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ABSTRACT

Science should not be presented as a collection of facts; it must be presented as an active dynamic subject. It should be used to stimulate young minds and encourage questioning. This is a publication designed to meet the needs of science teachers for a day-to-day reference in science. It was intended for the use of Peace Corps volunteers and science teachers in India. Contained in this publication are ideas and instruction for: (1) "Demonstrations, Practicals, and Practical Tests"; (2) "Science Clubs"; (3) "Investigations"; (4) "Science Fairs"; (5) "Improvised Apparatus"; (6) "Tools Use and Care"; and (7) "Laboratory Techniques." (CW)

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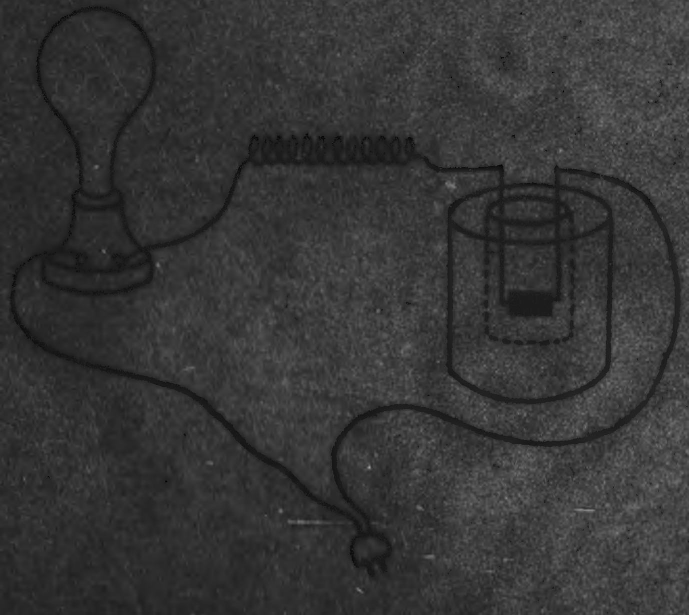
Science Teacher's Handbook



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Peace Corps

Science Teachers' HANDBOOK

Edited by

C. S. Rao

And

The American Peace
Corps Volunteers of
India 30

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Introduction

We are now in the Age of Science and Technology. Backward and developing countries like ours, which cannot afford even the basic physical facilities needed for educational institutions, will have to rely mainly on human resources. Every effort is necessary on the part of our science teachers to make the study of the subject by our children interesting and stimulating to make them realise the values of science for better understanding and living. It is, therefore, of utmost importance that our teachers should make full use of the equipment made available and where it is lacking they should improvise apparatus and teaching aids. The American Peace Corps Volunteers have been conducting workshops for the benefit of science teachers at seven centres in this state and the current publication is the outcome of their endeavour at all these centres. I am sure, the publication, laying down guidlines, will motivate our science teachers to more useful endeavours in the field.

L. Bullayya
Director of Public Instruction
Andhra Pradesh, Hyderabad.

Preface

What is the American Peace Corps doing in Andhra?

This is a question that has been asked in this State about the work of the Peace Corps organisation.

Part of the answer to this question can be found in the pages of this *Science Teachers Handbook*. High school science teachers asked for this Handbook and were instrumental in developing its format. This publication is an attempt to meet the immediate needs of Andhra's Science Teacher: a Handbook for day to day reference in science.

The Director of Public Instruction, in operating science workshop centres with American Volunteers, has made it possible for the Peace Corps to participate in this in-service training program, and gain the experience necessary for a publication of this type.

Science can no longer be rules of the past; science teaching must be exciting and dynamic. It must stimulate the minds of the students and encourage them to question.

This Handbook is not designed to teach new hypotheses or difficult concepts; it is based on the State syllabus and demonstrates new ways to teach old theories.

Our hope is that this Handbook indicates our committment and interest in the science teachers of Andhra Pradesh.

ANTHONY DEANGELO
Director,
American Peace Corps,
Hyderabad, A. P.

Foreword

I am happy to have been asked to write a Foreword to such a useful book as this. The book covers a wide range of topics. It gives a lot of information not usually found in any text book. The chapters on Investigations, Demonstrations and Improvised Science Apparatus give plenty of information useful to Classroom Teachers.

This book is the outcome of the experiences of a band of devoted volunteers (of the American Peace Corps) who ran Science Workshops in this State for more than a year. It is not an exaggeration to say that the Volunteers have done a really fine job though most of them are not specialists in any area of Science. This is, perhaps, the first attempt ever made in our country to place such a book in the hands of Science Teachers. I am confident, that properly used, this book will greatly help Science Teachers in their professional advancement, helping to make them better Science Teachers.

For various reasons, the Science Teacher in India did not learn to work with his hands and to design or build the apparatus required by him. At a time when the Government and managements of schools are not able to find adequate funds to properly equip school laboratories, there is any amount of need for the Science Teacher to improvise as many pieces of apparatus as possible and make his instruction effective and interesting. I am confident that this book will induce many Science Teachers to build the required apparatus and also to organise Science Clubs on sound lines. Though this book is written keeping in view the Science syllabus of Secondary Schools in Andhra Pradesh, I am sure it will be useful to Science Teachers in other States as well.

I wish and pray that the release of this book will be a step in the right direction in improving Science Education in our country.

C. Gopinatha Rao
Deputy Commissioner for
Government Examinations.

Acknowledgements

Teaching science is an art which can be acquired by practice. The tools for such practice are many, but must be modified a little to suit specific conditions. The degree of modification depends upon the nature of the local conditions in which the school is situated. The material in this book, like teaching tools, is modified to Andhra conditions and based on the experiences of American Peace Corps Volunteers working in Andhra Pradesh's Science Workshops: Ken Nisbet, Gary Dandurand, Dave Traxler, Henry Swezy, Jon Elsky, John Waterman, Mark Keintz, David Reichhardt, Dave Betts, Jim O'Rourke, Richard Fleischer, Steve Bossi, Jerry Brennig, Raymond Crow, Brian Flynn, David Morgan, Jim Meier, Tom Sowa, Ted Smith and Richard Krajec. Credit goes to the American Peace Corps Volunteers and the teachers in the science workshops for contributing the idea for this book. Credit and appreciation are also due to Mr. Gopinatha Rao, Deputy Commissioner of Examinations and Mr. Seshu Iyengar, Lecturer, Science Education Unit, for their very worthwhile suggestions and assistance.

Editor
C. S. Rao

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Demonstrations, Practicals And Practical Tests

Basic to any science program are demonstrations, practicals, and practical tests. By exercising the students' powers of observation and reasoning these activities provide an experience which the student requires to understand the methods of the scientist. Properly planned and executed, these activities can be effective tools for the teacher.

Practicals and demonstrations should be given, whenever possible, before the theory of the particular subject is taught. By guiding the student through a practical understanding of the subject the teacher prepares him for the theoretical explanation which will follow; the student can be led to "discover" the theory for himself. The students will learn the theory quicker and in greater depth than if the practical work is presented after the theory as an exercise in verification.

The practical test evaluates the students' success in grasping the relationship between the theory and practice of the science he studies. The test calls for a thorough understanding of theory and use of the skills of observation, manipulation, and critical thinking that he has developed. The practical test is a valuable experience for the student as well as a useful method of evaluation for the teacher.

The following are some points that may be helpful to the teacher when planning these activities.

DEMONSTRATIONS

Before doing a demonstration

Practice the experiment itself so that you are sure that it will work reasonably well in front of the class. Make notes beforehand so that you can keep the lesson running smoothly; include the important questions that you intend to raise before, during, and after the demonstration.

Opening the experiment

Keep the apparatus to one side in the classroom where it will be ready when you want it but where it will not distract the attention of the students while you are introducing the lesson. Precede the lesson by putting questions to the students that can be answered by doing the experiment. The apparatus can then be brought before them. Place it so that every student in the class can see what is happening.

Have students assemble the apparatus

If the apparatus is such that it must be assembled in front of the class, ask one or more of the students to do the assembly, one student doing each step. Be particularly careful that the students use the proper techniques since this will be a lesson in the use of apparatus. If different students are asked to do this for each demonstration, eventually every student will have the experience of handling the apparatus.

Have the students do the steps in the experiment

When the apparatus is assembled and the students know the function of each of the pieces, other students can be asked to perform the necessary steps in the experiment. The view of the class should not be blocked by the student doing the experiment. Another student can be asked to record readings or observations that are taken during the experiment. By calling on different students to participate in the experiment the attention of the class can more easily be held. Questions may be put to the students at every step in the experiment.

Drawing conclusions

When the experiment is complete, have the students study the data that has been recorded and attempt to come to conclusions about them. By asking the proper questions they may be guided to an understanding of the related theory.

Several students can now be asked to summarize the events and conclusions of the experiment so that the material can be fixed in the minds of the class. The students may raise questions about the experiment and the teacher can give suggestions to them about how they can do further investigations in their homes using improvised apparatus. It is also a good opportunity to develop ideas for investigation projects in the science club. With the understanding gained by the demonstration the students will more easily understand the theory.

PRACTICALS

Practicals must be carefully planned in order to take fullest advantage of them. Several points should be clear before presenting the practicals to your classes. Time is a major consideration; here the cooperation of the headmaster must be enlisted. For every science class the teacher should be assigned two adjoining periods once a week for conducting the practicals. Preferably these would be the last periods in the day so that the teacher has ample time to prepare for the class. Without this type of scheduling it may not be possible for the teacher to give practicals.

Equipment

If there is a lack of the necessary numbers or types of equipment, the teacher can relieve some of the shortage by improvising equipment himself or by having the science club members build them. The students will benefit from the increased numbers of apparatus and the skills that they learn.

Facilities

In some schools there are no facilities specially reserved for science activities or if there are some they may be insufficient. If you have a science room but no lab benches, the experiments can easily be done on the floor. If you have only a classroom, you may clear the benches to the sides of the room and use that floor space for the experiments. There is no objection to doing an experiment outside under a tree if that is the case.

Preparing lab notes

The teacher should prepare notes to guide the students through the experiments. The notes can either be duplicated on the cyclostyle machine or they may be written on the blackboard. The notes should be simple and brief so that the student has enough time to do the experiment carefully. These instruction sheets should contain only the information that is necessary to complete the mechanical parts of the experiment, so that the students can easily be guided through these steps, and second, questions about the experiment for the student to answer so that he will find it necessary to observe the experiment carefully and understand its relation to theory.

In the instructional part of these notes give directions for assembling the apparatus, a diagram might be useful, and list the steps that must be taken to do the experiment. Be sure to include precautionary notes if some part of the experiment has danger. The interrogative part will give questions that call to mind the student's relevant knowledge of the subject and point out the observations that should bring him to understand the significance of the experiment. An example of these lab notes is given on page 5.

Rotation by groups

If not enough apparatus is available for every student to have one piece, the students may be divided up into small groups. If there is only one piece of apparatus for each experiment, the experiments may be done by groups or individuals over a series of weeks:

1. Outline the experiments you will do during the term and divide your students into so many groups.

2. On the first week give the first group the first experiment and each succeeding group the succeeding experiment so that the last group does the last experiment in the first week.

3. In the second week the first group does the second experiment, the second group does the third experiment, and so forth with the last group doing the first experiment.

4. Repeat each week until each group has done each experiment once.

With this system only one set of apparatus and one set of lab notes are required for each experiment.

Present the experiments to your class

1. If you have a free period before the practical class, it is best to arrange the equipment then. Otherwise you can assemble it in one place the evening before and have it in readiness.

2. When the students come into the class, set them to work immediately copying the lab notes, questions, and data tables into their record books. If these are brief, this will take only five or ten minutes. In the meantime, you may be checking the apparatus to see that it is properly arranged.

3. When the students are ready, you may put a few questions to them. They may not know the answers but the questions can be discussed again after they have done the experiment. Their interest in the experiment may be increased.

4. If equipment is short, the students may be divided up into batches of five or six. Each group will need only one set of apparatus. Each student will do the experiment one time, unless this will be costly as in some chemistry experiments, and all members of the group will record the results each time. When all members have done it once, the group will have a small collection of data from which they can draw their conclusions. If you have enough pieces to give one set of apparatus to each student, that will be better since each student will have more time handling the apparatus.

5. When they have completed the experiment, have them disassemble and clean the apparatus and bring it to a central location.

6. When all students have finished, discuss with them the questions that you put earlier; this will help them to write out their answers to the questions given in the lab notes.

7. When the class is over, you can check the condition of the apparatus and return it to storage. You may enlist the aid of the science club members for additional cleaning or repair and storage of the apparatus.

Checking into the work done by the students

If the students copy the instructions and questions given in the lab notes into their record books, they will be able to record the data neatly and have all relevant information available for answering the questions. When you check their books, you will easily be able to refer to the questions that they are answering and the observations that they are discussing. The following steps may be taken to organise your review of their work:

1. Before the students leave the practical class, check their record books to see that they have all done the experiment and recorded the results.

2. They may then take the books home with them to write out a report of the experiment by answering the questions that are put to them.

3. At the beginning of the next class you may collect the books for checking.

Each report may be marked on a ten-point scale on the basis of neatness, accuracy and general comprehension of the experiment. At the end of the year these marks can be averaged and adjusted to some fraction of the total marks given to the student for the year.

SPECIFIC GRAVITY

Copy these instructions into your notebook. Do not write on this paper.

Aim: To find the specific gravity of liquid using the gravity bottle.

Apparatus: Specific gravity bottle.
Balance and weight box.
Blotting paper.

1) Find the weight of the dry empty bottle with its stopper. Enter this under A in the table which you have copied into your notebook.
2) Fill the bottle with water and replace the stopper. If there is a capillary tube in the stopper see that it is filled with water.
3) Using the blotting paper, remove all the liquid that is on the outside of the bottle stopper. All of the outer parts of the bottle must be completely dry.
4) Weigh the bottle again. Enter your measurement under B.
5) Empty the bottle and dry the insides with the blotting paper.
6) Fill the bottle with the unknown liquid, proceeding as in steps two and three above.
7) Weigh the bottle with the unknown liquid in it. Enter the result under C in the table.
8) Repeat the experiment five times following each of the steps above. Enter all measurements in the table.
9) Average the results in each column, adding each column of figures and dividing the sum by six; enter the averages at the bottom of each column.
10) Calculate the specific gravity of the unknown liquid by the formula given over the column. Enter the result

	A	B	C	B—A	C—A	$\frac{C-A}{B-A}$
Exp. No.	Weight of the empty bottle	Weight of the bottle with water	Weight of the bottle with liquid	Weight of water	Weight of unknown	Specific Gravity
1.						
2.						
3.						
4.						
5.						
6.						
Average						

Copy this table in your record book before doing the experiment.

Questions for the student to answer:

1) Why do you substract A from B and A from C ?
2) What are the possible errors that can occur in this experiment ?
3) What precautions should be taken in the experiment ?
4) How would you find the specific gravity of an oil ?
5) Can you use this technique for finding the specific gravity of a solution ?
6) Can you use this technique for finding the specific gravity of a powdered solid like sand ?
7) How else might you find specific gravity ?

PRACTICAL TESTS

Planning

The test may be given twice a year; this allows the teacher sufficient time to prepare the test and gives a wide variety of subject matter from which the test may be drawn. As with practicals, facilities need not be elaborate; for many questions any flat place will suffice. Shortages of equipment can be made good with the help of the students. Simple and easily available materials can often be used for these tests; a list of suggested materials is given at the end of Chapter V.

Preparing test questions

The questions should be framed so that the students are obliged to come to the solution by utilising the concept that he has learned in his theory classes and the techniques he has learned in his practical classes. The questions should be simple so that the student who has done his work faithfully can grasp the meaning of the problem quickly and set about finding the solution.

The question can easily be developed by taking a few general questions and altering them so that a great many specific problems are derived from a general type. An example of the development of questions is given on page 7. The types of questions that are suggested are not the same as those given in practical examinations. They are very simple and pointed. The equipment that is required is not complex and may easily be improvised.

Administration of the test

1. List out the questions to be used in the test and assemble the apparatus and materials that will be required.

2. Mark numbers with chalk at regular intervals on the benches or floor of the room to be used for the test. At each number place a set of apparatus and materials, being sure that similar problems are not adjacent to one another.

3. Write the questions to be used in the test on small slips of paper. On each set of apparatus write the number of the place where the set of apparatus and materials required to solve the problem will be found. Roll the papers up and place them in a cardboard box.

4. Line your students up in the order that they are named in the attendance register. Have one student come forward at a time and take a question from the cardboard box. The student will show the number of the question to the teacher so that it can be recorded and then goes to the appropriate place in the room to begin his test.

5. The student writes his name and class, the date, and his question on a sheet of paper. He then lists out the apparatus before him and writes a short paragraph on the experiment that he will do to answer his question.

6. When the student has performed the experiment, he writes his results, gives the paper to the teacher and leaves the room. The apparatus should be left as assembled so that the teacher may inspect it later.

For some questions, like the testing of gases, the teacher should observe the

Topic : Measurement

Sub-Topic : Measurement of volume

Questions :

1. **Find the volume of given piece of stone.**
2. **Find the volume of the glass in a given bottle.**
3. **Find the volume of a piece of wire twisted into a ball.**
4. **Measure the volume of a given amount of sand.**
5. **Find the volume of a lump of sugar given to you.**
6. **Measure the volume of salt crystals given to you.**
7. **Measure the volume of a brass key.**
8. **Measure the volume of an irregular object given to you.**
9. **You are given a cube of camphor. What differences are observed between measuring its volume with a glass cylinder and a foot scale ?**
10. **Find the amount of empty space among the sand particles that are given to you.**

student doing the experiment. Stock solutions that the students may require should be kept with the teacher.

Testing takes only about half an hour; preparations take about one hour. If two tests are conducted in a year, the total will be only three hours for each class.

Evaluation of the test

Marks may be assigned to the different steps that are required to carry out the experiment. For example, in finding the volume of an irregular body the following steps may be taken into into consideration:

1. Put the water or the appropriate liquid into a measuring cylinder and note its volume.
2. Introduce the irregular body into the liquid, using a thread.
3. Note the volume of the liquid again.
4. Find the difference between the two readings and identify it as the volume of the given body.
5. Repeat the experiment to check the results – the body must be dry for each repeated test.

Each step may be assigned two marks for a total of ten, or the ten points may be distributed among the steps according to their relative importance; points may be reserved for general performance. Two tests yearly would give the student a total of twenty possible marks in practical tests.

TEACHER'S NOTES FOR THE TEST

For the convenience of the teacher he may wish to prepare notes for each question in the test to systematize the test's administration and evaluation.

Here are some examples of teacher's notes:

Question

Prepare a sample of hydrogen sulphide and show a concrete test for it.

Materials to be supplied

1. A test tube; light bulb that has been cleaned out can be used.

2. Iron sulphide; aluminum sulphide can also be used; prepare it by heating aluminum powder and sulphur; metallic sulphides can be obtained from the residue left by the sparklers used at Deepavali.

3. Dilute hydrochloric acid.

4. Lead acetate paper; soak blotting paper in a saturated solution of lead acetate and cut into small strips.

What the student is expected to do

1. Put the metallic sulphide into the test tube and add dilute acid to it.

2. An effervescence is noted, indicating the evolution of a gas.

3. The gas evolved has an odor of rotten eggs.

4. The lead acetate paper is moistened and placed at the mouth of the test tube. It will turn black.

Question

Prepare a sample of sulphur dioxide and test it.

Materials to be supplied

1. A deflagrating spoon; this can be improvised.

2. Sulphur powder.

3. Heat source; spirit lamp can be improvised.

4. A wide-mouthed bottle such as a Horlicks jar.

5. Potassium dichromate solution or potassium permanganate solution.

6. A piece of cardboard.

What the student is expected to do

1. Put sulphur powder into the deflagrating spoon and heat it.

2. When the sulphur begins to burn, the deflagrating spoon is introduced into the bottle.

3. The bottle mouth is covered with the piece of cardboard.

4. The smell of burning sulphur is noted.

5. The student requests the acidified dichromate or permanganate solution and puts a small amount into the bottle, shaking it well.

6. The decolorization of the permaganate or the green color of the dichromate is noted.

Question

Find the weight of a given stone using the law of moments.

Materials to be supplied

1. Lever apparatus; this can be improvised.
2. A small stone.
3. A set of weights.
4. String or thread.

What the student is expected to do

1. Tie the string to the stone and hang it from one arm of the lever apparatus in such a way that it can be moved along the arm.

2. Tie a string to one of the weights and hang it similarly from the other arm.

3. Measure: the distance from the stone to the pivot (A): the distance of the weight from the pivot (B); the value of the weight (V).

4. Calculate the weight of the stones.
weight of the stone $= \frac{B \times V}{A}$

5. The experiment is repeated several times and an average weight for the stone is found.

Question

Draw the diagrams of the given leaves and describe their structure.

Materials to be supplied

A packet containing five different kinds of leaves.

What the student is expected to do

1. He draws the diagrams of the five leaves.

2. He describes the tip, margin, blade, petiole, and veination, using the appropriate technical terms.

Question

Show that plants give out water through their leaves.

Materials to be supplied

1. A plant in a pot.
2. A wide-mouthed bottle.

What the student is expected to do

1. He covers the mouth of the pot with newspapers.

2. The bottle is put over the pot so that all the leaves are inside.

3. The bottle is covered with a wet handkerchief.

4. The accumulation is noted.

SUGGESTED QUESTIONS FOR PRACTICAL TESTS

A. INTEGRATED SYLLABUS
VIII CLASS

Physical Sciences

1 Take a burette. Fill with water. Run out 25 ml of water into a measuring cylinder; find the percentage of error if any.

2. You are given a wooden cube. Find its density.

3. Demonstrate convection currents in water.

4. Trace the incident ray and reflected ray in plane mirror. Find the relationship between the angle of incidence and the angle of reflection.

5. Construct a magnetic needle with the given material.

6. You are given three substances. Heat them and record your observations.

7. You are given five substances. Classify them into elements, compounds and mixtures.

8. You are given a mixture. Separate the components.

9. You are given three oxides. Add dilute hydrochloric acid to each and record your observations.

10. Perform three experiments to show that the given liquid is an acid.

Biological Sciences

1. Draw the diagram of the given plant. Identify its vegetative parts.

2. There are five specimens of roots on the table. Classify them.

3. Arrange the apparatus to demonstrate osmosis. Draw diagram.

4. You are given five specimens of weak-stemmed plants. Classify.

5. Identify the modification of the stems given to you.

6. You are given five specimens. Identify the modification of sub-aerial stems.

IX CLASS

Physical Science

1. Arrange a simple pendulum and measure its length.

2. Find out the power needed for lifting the given body using a crow bar.

3. Find out whether the given piece of copper is pure using Archimedes principle.

4. Find out the specific gravity of the given liquid using Nicholson's hydrometer.

5. Find out the position of an image in a plane mirror.

6. Form an inverted real image bigger than the object using a convex lens. Measure the magnification.

7. You are given two salts. Identify which one is the sulphide.

8. Show that air contains CO_2 and water vapour.

9. You are given two salts. Find out which one is carbonate and which one is bicarbonate.

10. You are given two acids and one metal. What is the action of:

a. cold dilute acids.

b. hot dilute acids.

c. cold concentrated acids.

d. hot concentrated acids.

11. a. Add concentrated H_2SO_4 to sodium chloride. Test the gas, if any coming out.

b. Add concentrated nitric acid to the given metal. Identify the gas that comes out.

12. a. Add lime water to ammonium chloride. Identify the gas.

b. Add dilute hydrochloric acid to the given salt. Identify the gas.

Natural Science

1. Draw the diagrams of the given specimens. Identify the stipules.

2. What are the modifications of stipules in the given specimens?

3. Your are given some leaves. Classify according to their kind. Justify your classification.

4. What is the phyliostoxy of the given specimens.

5. Describe the modification in the given leaves.

6. Classify the kinds of Androcium in the given flowers.

7. Identify the joints in the given specimens.

8. You are given a group of specimens. Pick out an example of the following:

   a. Fibrous root system.
   b. Pistillate flower.
   c. Seeds containing endosperm.
   d. Cryptogams.
   e. Hunners bone.

B. HIGHER SECONDARY SYLLABUS

IX CLASS

Physical Science—Physics

1. Measure the sides of the given cardboard in C.G.S. and F.P.S. systems. Find the relation between the C.G.S. and F.P.S. systems (a) in length (b) in area.

2. Find how much space the given crystal occupies.

3. Find the average volume of a nail.

4. Calibrate this cardboard—rubber spring balance using iron washers as weights.

5. Find the centre of gravity of the given lamina.

6. Find the pressure of water at a depth of 10 cm, 15 cm, 20 cm and 25 cm.

7. Find out the path of a light ray passing through water. (A rectangular bottle is given to you.)

8. You are given a knitting needle. Magnetize it. How do you know that it becomes a magnet. Then demagnetize it.

9. Prepare a bichromate cell.

10. Show that liquids expand by heat.

Physical Science—Chemistry

1. You are given a mixture containing iron and sand. Separate them and calculate the percentage of sand in it.

2. You are given a mixture of camphor and chalk. Separate them.

3. You are given two sets of solutions. Mix the two solutions in the first set and tell whether it is a physical or a chemical change. Mix the two solutions in the second set and find out if it is a physical or chemical change.

4. You are given five packets containing five different substances Identify them and tell if they are compounds, elements or mixtures.

5. Conduct an experiment to illustrate displacement.

6. Prepare a saturated solution of the given substance (say salt, camphor etc.)

7. Neutralize the given base with the given acid.

8. Prepare a sample of chlorine and show one concrete test for the gas.

9. You are given two jars containing two gases. Find out which one is HCl, and which is chlorine.

10. What reaction will HCl have on sodium carbonate? If you notice any gas coming out, test and identify it.

X CLASS

Physical Science-Physics

1. Find the volume of the given marble using a measuring cylinder. Check it with the volume obtained by measuring the diameter.

2. Find the mechanical advantage of the single movable pulley.

3. Show that there is an advantage in using an inclined plane. Determine quantitatively.

4. Conduct a simple experiment to prove Archimedes' principle.

5. Find out the specific gravity of the given liquid using a U-tube.

6. Add the given sulphuric acid to water and measure the temperature change.

7. Conduct and experiment to show that water is a poor conductor.

8. Trace the path of rays falling on a plane mirror.

9. Arrange the two mirrors to get five images. Measure the angle between the mirrors.

10. You are given a convex lens. Obtain a magnified, real image of the candle.

Physical Science-Chemistry

1. Prepare a sample of hydrogen sulphide and show a concrete test.

2. Prepare 5% dilute sulphuric acid.

3. Prepare a sample of sulphur dioxide and show that it is highly soluble in water.

4. Prepare a sample of ammonia and show its solubility in water.

5. Identify the varieties of carbon from the given samples.

6. You are given three salts. Find out which salt is of calcium, sodium and potassium.

7. You are given three liquids. Identify which one is an alkali. Find out if it is a mild or caustic alkali.

8. Prepare a sample of calcium chloride from substances given to you.

9. Prepare a sample of sodium hydroxide.

10. Conduct an experiment to show that salts require water to keep up their crystal structure.

XI CLASS

Physical Science-Physics

1. Measure the diameter of the sphere with vernier calipers.

2. Weigh the given body using a physical balance.

3. You are given a potato. Drive a needle through it and make it stand on the needle.

4. Find the mechanical advantage in a single movable pulley.

5. Find the given object using Archimedes' principle.

6. Find the specific gravity of the given solution with the Hare's apparatus.

7. Find the melting point of wax.

8. Trace the path of rays through a prism.

9. Arrange the given lenses to form a telescope.

10. Prepare an electromagnet.

Physical Science-Chemistry

1. Separate the mixture of sand and iodine.

2. You are given three substances. Heat them and tell whether they undergo physical or chemical changes.

3. Conduct an experiment to illustrate conservation of mass (use a spring balance).

4. You are given some clay. Prepare the molecular models of water, carbon dioxide, hydrogen chloride, sulphur dioxide and oxygen.

5. Set up the apparatus for finding out the vapor pressure of a volatile liquid.

6. Prepare a sample of hydrogen chloride and show that it is highly soluble in water.

7. Set up the apparatus to find the equivalent weight of magnesium by the method of displacement.

8. Prepare a sample of oxygen with the given chemicals. Show a concrete test.

9. Prepare the oxide of sulphur and show that it is an acidic oxide.

10. You are given a mixture of two liquids. Separate them. Note to the teacher: give immiscible liquids.

XII CLASS

Physical Science-Physics

1. Measure the given wire. Without unwinding the wire ball find its length.

2. Set up a simple pendulum and find out its period of oscillation.

3. Find out the weight of the given stone using triangular law of forces.

4. Find out the weight of given body using the law of moments.

5. Show that the mechanical advantage of an inclined plane is equal to 1/Sin θ.

6. Verify Boyle's Law using the given apparatus. Note to the teacher: The apparatus consists of an injection syringe fixed to a wooden block. The end of the syringe is closed.

7. Find the specific gravity of the given liquids using common hydrometer.

8. Measure the pressure of water at a depth of 10 cm and 20 cm from the surface.

9. Find the velocity of sound by using the resonance apparatus.

10. Compare the strengths of the given magnets.

Physical Science–Chemistry

1. Prepare a sample of bromine and test it.

2. Prepare a sample of sulphur dioxide and test it.

3. Identify the acid and metallic radical in the given salt.

4. Test the salt for nitrate.

5. Test if the given salt is a sulphide.

6. You are given a concentrated acid. Find out if it is hydrochloric, sulphuric or nitric acid.

7. Conduct the charcoal test for the given salt.

8. You are given three metals. Find out the reaction of nitric and sulphuric acids in dilute and concentrated condition.

9. You are given a salt. Add sodium hydroxide to it. Identify the gas that is coming out.

Note: Give ammonium salt.

10. Arrange the apparatus for the dreparation of chloride in the laboratory.

Chapter 2

SCIENCE CLUBS

Science Clubs

The spirit of science is the spirit of discovery. Experience teaches that one of the most exciting and effective ways to impart to the students the joy and adventure of scientific discovery is through school science clubs. In this chapter we will further define the function of the science club and provide suggestions for its formation and activities.

HOW TO FORM A SCIENCE CLUB

In order to provide the students with the organizational facilities that are usually necessary to carry on science projects and essential for other science club activities, great care should be taken to organize the club soundly. The following are some points that ought to be considered.

Before the first meeting

There are certain initial duties of the sponsor in forming a science club. First, he should make arrangement with the headmaster for a time and place to meet making sure that there will be no conflicts with other activities.

The next concern should be the internal structure of the club. The club should function smoothly and encourage maximum student participation and responsibility. This means that:

1. The club offices should be responsible positions.

2. The club should draw on contributions from all its members.

3. The club should start small.

The first two objectives can be achieved through a good club constitution. For example, under the constitution the club president could have the responsibility of assigning committees to plan various club activities. If this is done properly, it will not only relieve you of much of the work involved in planning the club program but it can also involve every member in making decisions about club activities. The third point, starting small, suggests that it is best for you to start with a few interested students rather than a great number of students who join the club simply because of its novelty.

The relatively small initial size will help minimize the sometimes difficult problem of beginning a science club. As the club gains confidence in itself, you can easily increase its size to include more members, provided they are truly interested in science activities. Even with these restrictions your planning and guidance will be especially necessary during the first meetings of the club.

The first meeting

The first meeting is devoted to establishing membership qualifications, making schedules, dues, and business procedures. Thus these meetings are particularly important. The first meeting might follow this procedure :

1. Temporary Officers—at least a President and Secretary—are elected.

2. A committee is appointed or elected to formulate the constitution.

3. The club sponsor might then give a demonstration and discussion on the sort of activities in which the club can participate.

Forming the constitution

Before the next general meeting the constitution committee and sponsor should meet to deal with the following areas.

1. What should be the aim and purpose of the club ?

2. What will be its name ?

3. What should be the requirements for membership? You should remember here that it would be wise to ensure a relatively small and especially interested initial membership, probably drawn from the upper forms. It would also be good to establish some minimum requirements for retaining membership, say three independent projects per year.

4. When, where, and how often should meetings be held? Meetings should not be held so often as to become a burden on the members, but they must be held more often than once a month in order to keep interest up and to keep the club "alive."

5. Should dues be collected? How much?

According to the Department of Public Instruction, 50 Ps. per member per month may be collected (G. O. Rc. No. 790-H I-4/6 dated 1.12.64).

6. The business program for each meeting should be established. Although it is necessary to take some time at the beginning of club meetings to review the past meeting and receive committee reports, this part of the meeting should be kept as short as possible. The procedure of the business program might be as follows :

a. The President calls the meeting to order.

b. Secretary takes attendance.

c. Treasurer's report.

d. The minutes of the last meeting are read by the Secretary.

e. Discussion of any remaining old business is taken up by the President.

f. The President calls for new business.

7. Who shall plan the club program? Although it is usually wise for a club officer and the sponsor to be involved in club planning, it is best to appoint club members to various committees to plan club activities. Examples of these committees are :

a. Science Fair Committee.

b. Special Events Committee.

8. What officers should the club have and what should be their qualifications and duties?

9. When shall elections be held? The second and possibly the third meetings might include the presentation of the proposed constitution by the committee, discussion by the membership, revision if necessary, adoption of the constitution and election of officers. After that there might by a business meeting to begin considering a year's program and appointments of committees to plan specific activities.

Financing the club

Many science teachers complain that funds are not sufficient for a science club. However, a close look at the needs and available resources of science clubs may suggest otherwise. Each high school in Andhra Pradesh was directed by a Government order from the Director of Public Instruction in December, 1964, to set aside in the initial instance a sum of Rs. 300 for a science club (G. O. Rc. No. 790/H 1–4/6; dated 1–12–64). In addition to this each member can be required to contribute 50 Ps. monthly as dues. These funds together, or even the dues alone, in the event of lack of the Rs. 300, may be sufficient if your club uses inexpensive techniques as mentioned throughout this book. If, for instance, one student can bring in a few spent light bulbs, another used cells, another metal crate strapping, and so forth, you can get much useful material at no cost. Such items as deal wood, polyethylene tubing and electrical clips, you can have for a relatively low price. These ideas can help you to fit your club activities to its resources. These are only a few ideas; your club can think of many more.

SCIENCE CLUB ACTIVITIES

Many science clubs " disappear " not long after they are formed because the initial interest of the students is not maintained by a healthy schedule of activities. It is all too easy for a bravely–begun science club to lose it's membership when the usual program of making soap and "science notebooks" is exhausted. The variety and scope of science club activities can be greatly expanded by skillful and imaginative use of available resources. The following are suggestions about activities for your club and the part you should have in initiating them.

Role of the sponsor

The sponsor should take care that the primary function of providing interesting and educational experiences for the club members is being filled. One way of doing this is to be sure that the students participate as much as possible in club activities. The booklet "Organising Science Clubs" published by N. C. E. R. T. defines the role of the sponsor clearly : "It should be his constant endeavour, and also his earnest desire, to pass on the responsibilities of the club to its members and play the role of a guide".

In planning a program for the club you should discuss the types of activities and various possibilities for doing these with the club members who will be responsible for proposing a program for the year. Likewise, when the program is functioning, it is best to leave many decisions and other details to club members. You need only be sure that these things are done. Taking responsibility can be a good experience for a club member.

Guest speakers

It is possible that in your community there are people who could address your club on some area of science. Doctors, nurses, surveyors, engineers or other professional people are often pleased to participate in such functions. Government servants such as Social Education Officers, Agricultural Extension Officers, Animal Husbandry Officers, or Block Development Officers may be prepared to speak on matters of interest to a science club. Such a speaker might stimulate interest in students and will certainly broaden the student's scope of science.

Effective use of this occasion means careful preparation before the date of the speech. When your invitation is accepted, let the speaker know that there will be a question period after his talk so that he may adjust its length and so that he may be able to bring extra materials that will be useful in answering students' questions. Then have a club member do some reading or other research on the topic and at the meeting preceeding the meeting at which the guest will speak, the student can present a short introduction to the topic. The other club members will be better prepared to understand the talk and ask questions.

On the day of the talk it would be good to give a short demonstration of some club activity so that the speaker may become acquainted with your work. In the future he may be willing to serve as a resource person for other club activities such as advising for student projects or judging science fairs.

Field trips

The first step in planning a field trip, as in any other activity, is identifying your resources. What are the interesting geological or botanical places in your area? What industries are there? Are there mines or a dam? Each of these could provide an interesting trip; other opportunities may occur to you. As a guide and adviser to your club, it is not your job to decide where to go but to help the students learn what is available and decide for themselves.

Once a place has been chosen, there may be a report or introduction to the area of science concerned prepared by a student and presented before the trip. The time that is spent on a field trip may not be fruitful unless you are sure that the students are prepared to learn something that could not be learned as well in school.

Preparing and presenting an introduction to the subject is also a good experience for the student who does this.

Follow-up activities for individuals especially interested in a topic covered in a field trip might include a science investigation of some problem that the student has observed. There should be a report of the trip in your science club record book.

Science museum

The science museum should be interesting for all of the students. The purpose of a museum is educational, and this end is not well-served by unseen materials or by impressive or elaborate items whose significance is not explained. A dark room cluttered with mounted animals and useless equipment is little better than no museum at all. Your museum could consist of a simple table with improvised and unsophisticated displays that are clearly explained and placed where they can be seen by all students; a well-travelled corridor or a much-used classroom would be good locations.

Your role in such a museum would naturally be minor, if your club is enthusiastic. A program committee could decide on an arrangement to assign different members to work on the museum display for each month of the school year. You may have to provide suggestions yourself for possible areas to be covered or for particular points in a display to the concerned student. As an example, the first display could present an introduction to the operation of the radio (this could include a simple crystal radio and illustrations of the difference between tube or transistor radios and the crystal set). Another month might feature illustrations of the life cycle of a local moth and its significance to some local plants.

One requirement for placing a display in a conspicuous place in a school is that it should be changed regularly; otherwise its educational benefit will be wasted as time passes. If your club is a strong one, there will be a plentiful supply of materials for display.

Science bulletin board

Some members may also be responsible for maintaining a bulletin board in the science classroom. The bulletin board, if you don't have one, can be made simply by putting two or three layers of cardboard in a rectangular wooden frame. Cover the cardboard with a layer of flannel or some other cloth, and pictures or articles can easily be pinned to it. The bulletin board might consist of recent scientific developments reviewed in periodicals such as SCIENCE TODAY or the Sunday Standard. With your help some of the good language students can translate these for all the students to read. Placing a science club calendar on the board along with descriptions of recent or coming activities lets all your students know what the science club is doing. Just as in the science club museum, frequent changes of the bulletin board material keep up interest in the club

The science book

Keeping a science club book of project reports done by members will provide a continually growing resource for the future membership. Reading about a past project might challenge a student to proceed further in the study of the same topic. It will also serve to give members an introduction to the methods of science and assist the sponsor in teaching this topic to the club.

The club Secretary (or Editor, if one is elected) can take charge of the book. He might include science project reports, reports on field trips and reports on talks given by guests. The book should not contain too much of the formal details but should have a concise summary of the information that was learned; in the case of projects, a copy of the project report would be adequate. The science club book should be a reference and resource book as well as a history of the club's activities.

Maintaining and adding to the school apparatus

A science club can be a big help to the science teacher. If you have sufficient numbers of working apparatus, you can do your job better and your students will benefit. The first step in enlisting the services of the science club for this purpose would be to take a complete inventory of the available equipment and chemicals. An inventory would show clearly what types of apparatus are needed. If the list were available to each science teacher, it would help to ensure maximum use of the school's science resources.

Three or four sessions each year, perhaps during holidays, for apparatus construction and repair with the help of the club members will greatly increase your teaching resources. It will relieve you of some of the duties of laboratory maintenance and increase the student's skills with the tools and apparatus. Club members may also serve as student science assistants for classroom activities, helping to prepare demonstration apparatus, cleaning apparatus after use, and seeing that the laboratory or science room is well-organized and ready for use.

Demonstrations by the club

Your club can bring science to many members of the community. It can work with the Gram Sevak in giving demonstrations on health and hygiene. " The effects of insects on health " may be a good subject. The Agricultural Extension Officer may cooperate in a demonstration on the effect of fertilizers on plant growth or on erosion and its prevention. Elementary physical phenomena can be shown to local primary school students. It is also good to have a demonstration given at every club meeting, even if it is only repetition of a practical; this may provide a good incentive for regular attendance at the meetings.

Teaching a science topic forces the students to be sure of their own subject mastery. Planning for such a demonstration will take a team effort by the members of your club; your guidance in reviewing their program will be invaluable to them for their own sense of accomplishment and a successful demonstration will be even more so. A scientist must not only investigate but he must communicate; the skills of showing applications of science are important to your students' development.

Science projects

The best way the student can learn science is to do some himself. A primary goal of the science club ought to be to give the interested student the opportunity to expand his understanding of science in ways that this cannot be done in the classroom. Because of its freedom from the limitations of the classroom and the syllabus, the science club is well-suited to the job. It is an opportunity to give the student a real experience in science.

Making charts, models, and collections and doing experiments are good projects for students to do in science clubs. They require exercise of manual skills, powers of observation, and an understanding of the scientific theory that is involved, if they are done well. Many projects like these can be developed by extending the material that is given in the syllabus; students might prepare various salts to supplement the stock in the laboratory, make electrical cells as described in the text, find the specific heat of materials that are not taken up in the syllabus, or collect and classify types of leaves that are not discussed in class. Some students will benefit by writing special reports. Another good exercise is to have students give detailed descriptions of the application of science in everyday life; one project that has been done is to use the tests given in the texts for testing for the presence of some common chemical types of soils. Projects like these help to develop the students' scientific capacities.

To have a clear view of science, however, it must be understood as a process of investigation and inquiry. The skills of observation, handling and constructing apparatus, and the understanding of theory are relevant to this process but much more is required to give the student a real understanding of science. Investigative science projects for students are explained in the next chapter of this book.

Since students rarely suggest original projects, you will probably find it necessary to make specific suggestions for project work. One way to do this is to provide the club with a list of possible projects. Or if a student asks a particularly good question in class, you could suggest that he take the problem up in the science club. Often you will find that you may have to assign projects to students. Different types of projects may be assigned according to the ability of the student and a record of the project and its time limit may be kept in a book. From time to time, when doing a project, the student may come across obstacles that completely frustate him. You may sit down and review with him the progress he has made and make suggestions to help get him moving again. You might suggest a particular section of a book or explain to him a related investigation that would give him an idea of what to do next but it would not be good to give him a step by step list of instructions.

Science fairs

Included in the activities of the science club are organization of and participation in school science fairs. This is the logical conclusion of the work done in the science club and represents such an important topic that it is also given a separate chapter following the chapter on investigative projects.

Investigations

Not every student will make science his life's work, but every student will need at least a basic knowledge of the facts known to science and the ability to distinguish fact from fallacy. Science investigations promote both these objectives, since they require knowledge of scientific facts as a starting point for further discovery through the use of scientific method, which is really nothing more than precise, logical thinking. The following section contains suggestions which you may find useful in guiding your students through these investigations.

The steps involved in a science investigation, explained in detail in the following section, are given here in outline form.

1. Observation leading to a question.
2. Further observation and gathering of relevant information.
3. Formation of an explanation into an hypothesis.
4. Statement of a working hypothesis —predicting.
5. Testing of the hypothesis—experimenting.
6. Interpretation of data, resulting in
   a. acceptance of the hypothesis or
   b. modification of the hypothesis or
   c. rejection of the hypothesis.

HOW TO DESIGN AN INVESTIGATION

Forming a question

Any investigation begins with a question. The best question for a student investigation is one which the student has thought of himself. It may arise from something he has learned in class, or it may simply be something which has occured to him from observing his daily surroundings. The source of the question is not important. What is important is that the student will be interested in it because it is his own question.

When the student comes to you with his question, you should offer him encouragement by suggesting to him various books and other sources where he can find information relating to his problem. It may be that he will be able to find the answer in a book and there will be no opportunity for an investigative project. But if he reads the information available to him and still cannot find the answer, or if the answer given to him in a book or scientific journal does not satisfy him completely, he has the beginning of an investigation, a question to which no suitable answer is avaliable.

Utilizing your sources of information

Although the student was not able to find the answer to his specific question from his reading, he should have been able to find at least some information relating to his question. You should encourage the student to do further reading so that he will be familiar with all available information relating to his topic.

He may also consult competent people living in your area such as scientists, college lecturers, science or medical technicians, doctors, or nurses, who may have knowledge of the subject in which he is interested.

At every step of the investigation, you should only guide and counsel the student. It is his investigation, and he must do his own work. He will have far greater confidence in himself and a deeper sense of accomplishment if he completes the investigation knowing that he is responsible for the results.

Forming the working hypothesis

From the facts available to the student from his reading and observations, he should now try to form an hypothesis; that is, an attempted explanation of his question based on the known facts. The hypothesis is actually an intuitive statement based on the scientist's knowledge. From this statement the scientist makes a logical prediction which will be the basis for his experiment. The hypothesis and the prediction resulting from it are then usually put in the form of an "If . . . then" statement.

Let us suppose that an investigator's problem concerned the rate of fall of various free-falling objects. On the basis of his observations and information available to him, he might be led to say that weight determines the rate of fall. Then the formal statement of his hypothesis and prediction might read: *If* the weight of a free-falling object determines its rate of fall, *then* the greater the weight of the object, the greater will be its rate of fall. The "if" part of the statement is the scientist's assertion based on his observations and information. It represents a summary of his attempt to answer his own question. The "then" part of the statement is what should logically follow if the "if" statement is correct. This "then" statement will determine the course of action the scientist will take to test his hypothesis. The "If...then" form of the hypothesis is called the working hypothesis, for it contains the scientist's explanation of a phenomenon and a logical prediction based on that explanation. By testing the prediction, the scientist will know if his explanation is correct.

You will probably have to give some help to your student when he is ready to make a formal statement of his working hypothesis. He may have some trouble in stating his explanation precisely. And since the prediction based on this explanation will determine the test of his hypothesis, it would be wise for you to make sure that the formal statement of the working hypothesis is exactly what the student wishes to say.

Once the formal statement of the working hypothesis has been agreed upon, the student will have to devise an experiment to test his hypothesis. Here again your guidance will be valuable. You should not devise the test for him, but you may advise him where he may encounter trouble. By putting questions to him, you can bring to his attention possible sources of error. If he comes to you with problems, you can offer suggestions.

Designing an experiment

The design of the experiment is the student's plan of attack. He should plan each stage of the experiment step by step beforehand so that he has a clear idea of how he will proceed to solve his problem. He should take into consideration possible sources of error and design his experiment so that these errors will be eliminated. This is the proper function of experimental design, eliminating error before it has a chance to occur. Here clear thinking and attention to detail are especially important for the investigator, for an oversight could easily make the results of the experiment invalid.

The criteria which must be satisfied before the design of the experiment can be said to be correct are validity, adequacy of the test, and adequacy of the instruments. For his test to be valid, the student must leave no doubt that it shows exactly what he says does; that is, there can be no other possible explanation for the results of the experiment but the explanation put forward by the student.

Variables: In order to explain how the student is able to eliminate all possible explanations but one, it will first be necessary for us to define a few terms. A "variable" is any factor which may affect the results of the test. For example, in our falling bodies investigation such factors as weight, height of fall, shape, surface area, or starting velocity would all be considered variables, since a variation in any one of them might affect the rate of fall. You can understand from this that in his investigation your student must take into account any factor which could possibly influence his results. The "*independent variable*" is the factor which the student says is responsible for the effects he has observed. For example, in our falling bodies investigation weight is the independent variable because the investigator believes that it is the difference in the weights of objects that causes the difference in their rate of fall.

One fact was understood by the investigator which had not concerned him until now: rate of fall (speed) is equal to distance/time. The investigator reasoned that when distances are equal and times are not, then speeds cannot be equal. Therefore, he reasoned, rate of fall can be measured by noting the time it takes for an object to fall from a known height. According to his hypothesis, the amount of time which it took an object to fall would depend on the weight of that object. Time, then, became his *dependent variable*. If the hypothesis is correct, the dependent variable (time) is dependent upon the independent variable (weight).

Direct Controls: The objective of experimental design is to exclude all possible explanations for the effect observed except the one that the investigator is advancing. To do this, the student must control all variables except the independent and dependent variables. That is, all other variables must be kept constant during the experiment. This enables the student to say that the effect observed in the dependent variable is due to the action of the independent variable and nothing more. For example, in devising a proper test of his hypothesis, our investigator would have to drop various objects from exactly the same height and record the amount of time it took for them to fall. These objects should differ in no significant way but for weight. He must use objects of the same shape, volume, and so forth. He would then be exercising direct control over the variables.

Indirect Controls: Since such objects would be difficult to find, control must be achieved by indirect means. This is often the case, and here again your guidance will probably be required by the student. If our investigator were forced to use large and small lead balls for the heavy and light objects, he would be allowing the size or surface area variable, as well as the weight variable, to change simultaneously. And since the logic of experimental design states that we must be able to assess the effects of all manipulated variables on the dependent variable, this case would not be acceptable scientifically. For an investigator would not be keeping all variables besides weight constant and if he did find differences between the large-heavy lead ball and the small-light lead ball, he could not say that they were due to only largeness or only heaviness.

What then is called for is a large light stone, or a small heavy stone; by using materials differing in density, our experimenter would be able to control the size variable indirectly. Thus he would have at least three groups of objects. Porcelain balls, with a diameter as large as the large lead balls but whose weight were the same as the small lead balls.

By comparing the lead objects first, the experimenter would get an idea if either the weight or the size variable were significant (while he would be unable to assess which one it was). Then by comparing the times of the small lead ball with the large porcelain ball, the experimenter would be able to assess the effect of size (since weights are equal) and finally by comparing the times of the large lead ball with the large porcelian ball, the experimenter would be able to assess the effects of the weight variable (since the sizes were equal).

Of course there are number of other methods available to the experimenter for controlling this variable (such as using hollow balls and solid balls of the same size) but our experimenter chose this way of controlling his variables indirectly.

Control and Experimental Groups: We can now define two more terms. *Con-*

trol groups are those groups in which the independent variable does not play a part. For instance, in an experiment using large and small lead balls and porcelain balls as large as the heavy lead balls but weighing only as much as the small lead balls, the independent variable (weight) would not be a factor in determining differences in falling speeds between the porcelain balls and the small lead balls (remember their weights are equal). Therefore, the small lead balls as a group are known as a control group (weight, the independent variable, should not play a part in making the small balls fall as fast as the large lead balls). Likewise, the large porcelain balls are also a control (weight could not make them fall faster than the heavier large lead balls), but they are controlling for the size variable also. In this experiment, therefore, there are two control groups and there is one *experimental group*; that is, a group of large lead balls in which the independent variable is thought to play a part in determining falling speed.

The importance of a control group will be realized when the student begins to interpret his data, for the control group allows the investigator to say definitely whether or not the independent variable has an effect on the dependent variable. If there is no difference between the performances of the control groups and the experimental group, then the investigator must conclude that his hypothesis (weight determines falling speed) is not correct for the independent variable is seen to have no effect on the phenomenon he is examining. If, however, there is a recognizable difference between the performances of the control groups and the experimental groups, the investigator can reasonably say that his hypothesis is correct.

An example from agriculture may be used to better illustrate control groups and experimental groups.

Question: What is the effect of nitrogenous fertilizers on the production of maize?

Working hypothesis: *If* nitrogen is essential for plant growth and useful in large quantities, *then* the plants which receive significantly larger proportions of nitrogenous fertilizers in their soil will produce more maize than those which are not treated with such fertilizers. In order to conduct a valid experiment the natural content of the soil, the amount of water the plants receive, the amount of sunlight exposure, and so forth must be identical for all plants. Under these conditions the soil of one set of plants is given 5 kg of fertilizer, another set 3 kg, another 1 kg, and a control group is given no fertilizer. Thus, there are three experimental groups (5 kg, 3 kg, 1 kg) and one control group (no fertilizer).

Reliability of the test : When your student is convinced that the design for his experiment is valid, he must face the second criterion for experimental design—reliablity of the test. He must give proof of the experiment's reliability by showing that it can be performed on repeated occasions in an identical manner with equivalent results.

To meet this criterion, the experiment for most investigations will consist of several trials, since one trial will not be sufficient to prove anything conclusively. For instance, in our falling bodies experiment the investigator cannot be content with simply recording the times which it takes for three balls (one small, one large, and one the same size as the large one but as light as the small one) to fall from a given distance. The results of any one trial might be due to some random error or chance. Therefore, the student must perform several trials so that he can show conclusively that the same results will be obtained every time the experiment is performed. For the falling bodies experiment, the investigator must have an assortment of large and small lead balls and a control group of large porcelain balls, each equal in weight to one of the small lead balls but of the same size as his large lead balls. The times for these balls to fall from a given height can then be measured and compared through a series of trials, and the investigator will have conclusive proof that his results are accurate and consistent. By meeting this criterion the student shows that his results deserve a position in the body of scientific knowledge. His experiment will yield the same results for other investigators using the same techniques and the same apparatus.

Adequacy of the instruments: We now come to the third criterion for proper experimental design. By adequacy of the instruments we mean that the measurements of the variables that he is taking into account are resonably accurate and consistent. In the example of the falling bodies, our investigator's stones must be equal in all things except weight. Since we have seen that this would be very difficult, his control group (large porcelain balls equal in weight to the small lead balls) must be equal to the large lead balls in volume, surface area, etc. They must be released from the same height with the same initial velocity (probably zero) and the experimenter must be able to measure the amount of time that it takes for each stone to reach the ground.

Before beginning the experiment the student will have to assemble the apparatus necessary for completing it. It will often happen that apparatus is not available to the student. In such circumstances improvisation becomes invaluable. By using his own ingenuity and the skills that you can pass on to him, the student should be able to improvise the apparatus needed for his experiment.

While building the pieces, a sharp eye should be kept for the accuracy that they will give. If the apparatus will give reasonably accurate and consistent results, the criterion of adequacy of the instruments can be satisfied. No instrument is perfect and in all cases a margin of error must be considered when designing the experiment and evaluating the data. Improvised apparatus may be more or less accurate than commercial models depending on the builder's skill; the degree of accuracy should simply be accounted for by the experimenter. Student investigations using improvised apparatus do not require a high level of precision.

HOW TO CONDUCT AN INVESTIGATION

Schedule for work

The student should now prepare a work schedule, allowing himself a specific amount of time for each remaining step of the investigation. He still must construct the apparatus, conduct the experiment, and interpret the data. The time allotted for his investigation as a whole and for each part of the investigation will vary according to the nature of the investigation and the free time which the student has at his disposal. For instance, one student may allow two weeks for the construction of the apparatus, two weeks for conducting the experiment, and two weeks for interpreting the data. An extra week allotted to overcome any unforeseen difficulties would mean that the entire investigation should be completed within seven weeks. Another student may allow only one week for the construction of the apparatus, six weeks for conducting the experiment and two weeks for interpreting the data. With an extra week allotted to the unexpected, the investigation should be completed within ten weeks.

For some investigations, the apparatus needed for the experiment may have to be invented by the student. This often happens when the student knows of no piece of apparatus which he can use to perform the desired experiment. At other times a known piece of apparatus will have to be modified by the student to fit his specific needs. In such cases, the time for designing the apparatus should also be allotted in the work schedule. For example, three weeks for designing the apparatus, two weeks for constructing the apparatus, three weeks for conducting the experiment, two weeks for interpreting the data, and one week for extra difficulties, a total of eleven weeks.

These are only examples of work schedules. Each student will have to set his own schedule so that his investigation will be conducted reasonably and efficiently. He should know at all times how much work he has remaining and when he will be finished. You may aid the student by pointing out some of the special difficulties he may have to face and advising him to allow sufficient time for overcoming these, but the final decision for time allotment will have to come from him.

Constructing the apparatus

When the student is constructing the apparatus, you may aid him with suggestions which will make the work easier for him, but he should do his own work. This will build up his confidence in himself, and he will learn to be independent. Your criticisms of his work should be constructive. You can point out inadequate workmanship and ncourage him to improve it. The eaccuracy of his measurements will depend upon the precision of his apparatus; he cannot be satisfied with poor quality work.

Conducting the experiment

Logical techniques : In conducting the experiment, the student should be methodical and efficient. This stage of the investigation should cause him no dfficulties if he has learned proper scientific technique during practicals and demonstrations. He will know that he must be consistent in his methods and logical in his thinking. If he has designed his experiment according to the guidelines we have alrady discussed, most sources of gross error will have been eliminated. The others will be minimized, if he uses good scientific technique and common sense.

Objective Observations. It is essential that you teach the student the value of making accurate observations. He must record things exactly as they happen. A student may allow his hypothesis to influence his observations; that is, he records what he thinks should be taking place instead of what is actually occur-ring. During an experiment, a scientist must be completely objective. This is as true for the student investigator as it is for the professional scientist working in a research laboratory. It often happens that in disproving an hypothesis, the investigator finds a clue that leads him to a far greater discovery.

During the course of the experiment, many new questions may occur to the student due to his observations. He should keep a record of these questions, but he should not let them divert him from his goal of finding an answer to his original question. These new questions may be taken up later as the basis for futher investigations.

Keeping records: You must impress upon your student the necessity for keeping a complete record of his experiment. This will be essential when the time comes for him to interpret his data and write a report of the investigation. If he has no records,he will have no data to interpret. In most cases, the student will be conducting his experiment over a period of weeks, and his data will be hopelessly jumbled and forgotten if stored only in his head. Before beginning the experiment, the student should prepare a form on which the observations are to be recorded. This form will usually include a list of all variables. The condition of each variable should be recorded at each trial.

Interpreting the data

The final task of the student is the interpretation of his data. Actually this is no more than a task of clear, logical, objective thinking. In the course of the experiment, the student will probably have accumulated a large amount of data. He must arrange this methodically and summarize the results from which he will judge whether to accept, modify, or reject his hypothesis. If both the hypothesis and the experimental design are correct, the dependent variable will be found to change as the independent variable changes. If the results of the experiment do not show this to be true, then either the hypothesis or the experimental design is incorrect. If the student feels confident that he has satisfied the criteria for proper experimental design and that he has used good scientific technique in conducting the experiments he can only conclude that his hypothesis is incorrect and he will have to modify or reject it.

The meaning of one term that is used very often with reference to data appears to be obvious, but it is so important that it deserves special mention. The concept of "difference" represents the rationale behind the use of controls in the design of the experment. The significant data in our example were the differences in time in which the stones fell, not necessarily the actual times of fall. The differences are based upon the performance of the control group. If the hypothesis in our example were to be supported, there would have to be a difference in the times of fall of the light and heavy stones. We will follow the interpretation of the data arrived at in the example to its conclusion as a demonstration of the complete process.

After various trials, if the investigator found differences in time of fall between the heavy objects as a group and the light objects as a group regardless of their sizes, he could conclude that the differences in the results were due to weight only. Therefore his hypothesis would be proved, since the dependent variable (falling time) would be shown to vary as the independent variable (weight) varied. But if he found that the large objects as a group fell slower than the small objects, regardless of their weight, he would have to conclude that the differences in falling times were due to the size variable and had nothing to do with the weights of the objects. Therefore his original hypothesis would be incorrect.

Viewing his results our investigator was able to reach a conclusion that forced him to reconsider his thoughts on the subject altogether. He found that no matter how many times he did the experiment it was the small objects of various weights that fell faster than the large objects of various weights. Thus he found that size, not weight as in his hypothesis, appeared from the results of his experiment to be the variable which caused differences in rate of fall. His hypothesis was not supported, and he was forced to revise it. He reasoned that large objects fall more slowly than small objects because their larger surface areas subject them to more air resistance. His new hypothesis asserted that all objects fall at the same rate except in so far as the rate of fall is affected by the size of the object due to air resistance, all other variables being controlled. This hypothesis he could prove to be correct in repeatable experiments.

Helping your students interpret their data

It may be necessary for you to give the student some help in interpreting his data, but in most cases this may not be best. Since interpreting data is largely a matter of clear thinking, the student should draw his own conclusions. The help you do give can be in the form of questions such as: What do these figures prove? Why? Are there any other possible explanations for their results? How do you know there is not? Have you taken into consideration all of your data such as . . . ? In this way, the student may learn to think for himself, to have sound reasons for his conclusions, and to stand by his decisions.

HOW TO REPORT AN INVESTIGATION

Purpose of the report

When the student has finished his investigation, you may want him to make a report on it to the science club, or you may feel that he should enter it in the school or district science fair. In either case, in order to explain the entire investigation comprehensively, he should write a report which will describe clearly, concisely, and accurately every step which he has taken. The student will probably require little encouragement to write such a report, for he should be proud and eager to gain recognition for the work he has done. The following outline *cum* explanation should be useful to you in showing the student how the report should be made.

Outline of a typical report

I. Introduction

A. *History*: This section is intended to make the reader familiar with the background of the problem which the student has investigated. Consequently, he should summarize all the facts which are necessary for an understanding of the problem. A brief history of the problem is also appropriate. It is important to remember that the reader may be totally ignorant of the background of the investigation. For him to be able to come to the same broad understanding of the problem as the student, the perspective of the investigation and the necessity of an answer to the question posed must be made absolutely clear.

B. *Hypothesis*: At the end of the introduction, the student should state his hypothesis (the reasons for the hypothesis should already have been stated). He then should state his prediction based on this hypothesis and combine the two into his working hypothesis.

II. Experiment

A. *Subjects*: If human subjects are used for the investigation, relevant subject variables such as age, sex, height, weight or any others which might be crucial to the experiment should be described. If the subjects are animals or plants they should be described in the same manner (genus, age, etc).

B. *Apparatus*: This section should contain a concise but detailed description of the apparatus used in the experiment. The description should be very specific. Weights, strengths of solutions, lengths, volumes, or any other variables relevant to the experiment should be defined and given. For instance, if the student used light and lenses in experiment, he should specify the type of light (for example, a 100 watt frosted Bajaj light bulb), the focal length of the lenses, their type, quality, and other dimensions. The arrangement of the apparatus must also be described; here a diagram will be useful. The reason for this detailed description is to allow any other experimenter who reads the student's paper to duplicate his experiment and obtain the same results.

C. *Procedure*: The student must give a description of the controls and variables used and explain the procedures for the control and experimental groups. He must explain the reasons for the controls. He should also describe the actual techniques used in conducting the experiment. This description should be adequately detailed so that the reader will be able to duplicate precisely the mechanics of the experiment if he wishes.

III. Results

In this section the student simply presents his results. This is usually done in the form of graphs and tables. Any mathematical processes which were performed on the data must also be described briefly. This section is the easiest to write because all the author is expected to say is: "The results are presented below"; and the reader will refer to the tables and graphs.

IV. Discussion

Essentially, this is the final section of the paper. It consists of the student's interpretation of his data and his conclusions. Some students may attempt to go beyond the actual data by theorizing. You may have another Newton in your class.

This section also includes a statement of the limitations of the experiment. If the student observed anything other than the independent variable which he thought might be influencing his results, he must mention it here. In general, this section allows the writer to mention anything which he feels is relevant to the actual data and to draw whatever conclusions he feels he is able to make from the data.

V. Summary

The student should end the report by summarizing all previous sections. This gives the reader a brief overview of the entire work and therefore must be concise and factual.

EXAMPLES OF INVESTIGATIONS

In this section you will find some examples of investigations in chemistry, biology and physics. This section is divided into three parts giving examples of reports in each of these disciplines. Moreover, each of these sections contains investigations which vary in completeness. The first two are complete reports and are meant to serve as models for your students. The ones which follow these are incomplete and are meant as an exercise in designing your own investigations and drawing inferences from data. If you can satisfactorily answer the questions at the end of each incomplete report, you can feel confident in your ability to guide your students in this work.

The introductory section to each of the following investigations is somewhat larger than will be required for most student investigations. Shorter, adequate introductions may be written by your students.

Ending each section is a small list of questions which you can encourage your students to answer experimentally, This list, however, makes no attempt to be complete but should serve only as a starting point for you.

Chemistry

DIFFUSION RATES OF SOLIDS THROUGH WATER

Introduction

Many observations have shown us that molecules of solutes are always in motion in a solution. Convection currents of fluids are studied by placing hot dyes in the bottom of a cool beaker of clear fluid. Diffusion of gas vapor (NH_3) through a solution of water with blue litmus dye gives us a way to watch diffusion. Finely divided particles of solid suspended in water or other liquids and viewed through a microscope may be observed to move about in a helter-skelter manner. The movement of these particles is the result of many collisions between microscopic molecules. As the temperature increases the number of collisions of these molecules increases, and the visible particles appear to move faster.

However, particles of different compounds do not move at identical rates. Different colored inks placed in water diffuse at different rates, even though the water temperature is kept constant.

The speed of movement of the visible particles depends upon the temperature. It also seems to depend upon other factors. One of these factors might be the size of the particle. That is, the force of gravity may slow the upward rate of diffusion of particles with relatively large mass. Ions of salts dissolved in water may behave similarly. If the upward diffusion rate depends upon the molecular weight of in ion, then salts of high molecular weight will diffuse more slowly than salts of low molecular weight, provided that the water is not disturbed and remains at constant temperature.

Experiment

Procedure: Two 100 ml graduated cylinders were each filled with 100 ml of clear water.

A crystal of $Cu\ S0_4$ of 1.05 grams mass (Cu^{++} is blue) was placed gently in the bottom of one cylinder; a 1.07 gram crystal of $K_2Cr_20_7$ ($Cr_20_7^{--}$ is orange) was placed in the bottom of the other cylinder. The heights of the crystals were recorded, thus determining the zero point for diffusion in the cylinders. At hourly intervals the heights of the colored solutions were recorded for both salts.

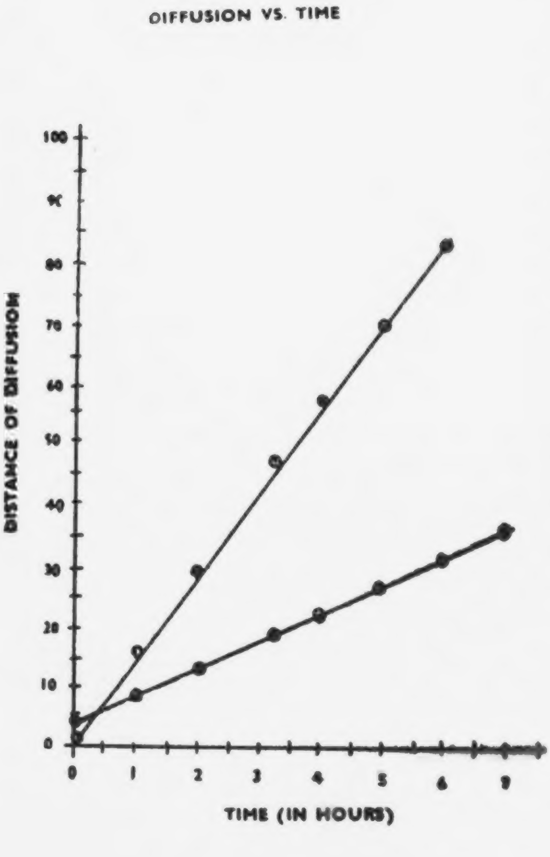
Results:

The results are given below:

Room Temperature		28°C.
Weight of $CuSO_4$		1.05 gr.
" "	$K_2Cr_20_7$	1.07 gr.
Molecular weight of	$CuS0_4\ 5H_20$	249.70
" " "	$K_2Cr_20_7$	294.00
" " "	Cu^{++}	64.00
" " "	Cr_2O^{7--}	216.00

Reading Number	Time	Level of $K_2Cr_20_7$ Solution	Difference in Levels	Rate of Diffusion
1.	9:00	4.6 ml		
2.	10:00	8.8	4.2 ml	4.2 ml/hr
3.	17:00	13.2	4.4	4.4
4.	12:15	19.3	6.1	4.9
5.	13:00	22.8	3.5	4.7
6.	14:00	27.1	4.3	4.3
7.	15:00	31.1	4.0	4.0
8.	16:00	35.4	4.3	4.3
Total	7 hours		30.8 ml	Ave. 4.4 ml/hr

Reading Number	Time	Level of $CuSO_4$ Solution	Difference in Levels	Rate of Diffusion
1.	9:00	2.8 ml		
2.	10:00	16.0	13.2 ml	13.2 ml/hr
3.	11:00	29.8	13.8	13.8
4.	12:15	46.9	17.1	13.7
5.	13:00	57.4	10.5	13.0
6.	14:00	71.2	13.8	13.8
7.	15:00	84.4	13.2	13.2
Total	6 hours		81.6	Ave. 13.6 ml/hr



Discussion

The results were fairly consistent: linear curves were obtained showing that the rates of diffusion were constant for each salt. However, different salts appear to diffuse at different rates—the rate for copper sulphate was almost thrice that of potassium dichromate. This ratio, however, is not inversely proportional to the molecular weights of the two salts: that is, even though the molecular weight of potassium dichromate is about 1.2 times that of copper sulphate, the copper sulphate did not diffuse at 1.2 times the rate of diffusion for potassium dichromate.

But the rates of diffusion did appear to be related to the molecular weights of the colored ions: $Cr_2O_7^{--}$ (molecular weight is 216) moved about one-third as fast as Cu^{++} (molecular weight is 64). The hypothesis may have been correct f it had read: "If the molecular weight of the indicator ion is high, then the rate at which it diffuses upward through a solution of water is low, provided that the water is not disturbed and the solution remains at a constant temperaature. "

However, other factors may influence the rate of diffusion: the copper ion has a positive charge compared to the negative charge of the dichromate ion. A test using ions of the same charge might give more conclusive proof to the hypothesis. Also, the unobserved ions in the experiment, SO_4^{--} and K^+ might have affected the experimental results. By using a common indicator ion with different invisible ions, one could determine the effect of the unobserved ion.

Gravity may be the factor which causes the molecular weight to influence the rate of diffusion. If we had hung the salt crystals at the top of the solvent and measured the rates that the salts diffused down through the solution, the opposite result might have been recorded—the heavier ion might have diffused at a higher rate. We can test this hypothesis (that weight determines the rate of diffusion) further by corking a graduated cylinder and placing it on its side. This way the salt would diffuse horizontally and gravity would exert no influence on the rate of diffusion.

Too many doubts have arisen in the experiment to allow us to accept the results as conclusive of any hypothesis, the colored ions were different in charge, obviously the uncolored ions were different, and only upward diffusion was tested.

Summary

An experiment was conducted to observe the relationship between the rate of diffusion of an ion and its molecular weight. At the bottom of a 100 ml graduated cylinder filled with clear water, a crystal of $CuSO_4$ was placed, and in another was placed a crystal of $K_2Cr_2 0_7$, and the heights to which the colored solutions had traveled were recorded hourly. It was found that the rate of diffusion was constant for each of the ions and that it varied inversely in relation to their molecular weights. Doubts arose as to the validity of the experiment since the ions used were of different charges and no account was taken of the unobserved ions.

SOLUBILITY

Introduction

If a lump of ordinary table salt is dropped into a beaker of water it disappears gradually. The salt is said to dissolve in the water. Careful examination of the water with a microscope does not reveal the dissolved salt. By testing the liquid, we can tell that the salt present in the water. The molecules of salt have become mixed with the molecules of water so that the same degree of saltiness is detected in all parts of the water. More salt may be added; it, too, dissolves. But if this process of adding is continued, ultimately a point is reached where salt no longer dissolves. Some of it remains in the bottom of the beaker. A mixture of dissolved salt and water of any concentration is a solution.

Salt is a compound, composed of positive ions of a metal or radical and negative ions produced when certain acids transfer protons to a base. All true salts by this definition are electrovalent substances. They are strong electrolytes and are completely ionized in water solutions, i. e., current will be conducted through such a solution.

Water is a dipole solvent. The water molecule contains polarcovalent bonds which are unsymmetrically distributed; there are negative and positive regions formed on the molecule of water.

When a few crystals of salt are dropped into a beaker of water, the water dipoles immediately exert an attractive force on the ions forming the surfaces of the crystals. The negative (oxygen) end of several water dipoles exert an attractive force on the positive sodium ion. Likewise, the negative chloride ion has an attractive force exerted on it by the positive (hydrogen) end of other water dipoles. This weakens the bond by which the sodium and chloride ions are held together in the crystal lattice and they are torn away to diffuse throughout the solution, loosely bonded to these water (solvent) molecules. In this way the salt crystal is gradually dissolved and the (Na & Cl) ions spread throughout the solution. The attraction of water molecules to ions of salt is called hydration.

The rate at which the salt dissolves can be increased by three different methods. Stirring moves the freed ions away from the crystal lattice, so other ions can be attacked by the water dipoles. Breaking up the crystals into smaller ones increases the total surface area of NaCl and allows more ions to be in contact with the solution. Heating causes an increase in Brownian movement (molecular movement) and the solution action is speeded. Heating also increases the solubility of the substance and a larger amount can be dissolved at higher temperatures.

Extensive hydration or dissolving of salt ions ties up a substantial portion of the solvent molecules. This reduces the number of free water molecules in the space separating hydrated ions of opposite charge. Attraction between the ions becomes stronger and the crystals begin to form again.

Not all salts are soluble in water. Silver chloride is a white salt that will not dissolve in water. Many other salts are also insoluble in water. But the amount of each soluble salt that goes into solution is different. From past experience in the laboratory with cupric sulphate crystals it has been found that a large amount of this salt is needed to form a saturated solution at 100°C. But an equal amount of sodium chloride dissolved in an equal amount of water at the same temperature will have many crystals remaining on the bottom of the beaker.

There is a large difference in molecular weight between cupric sulphate (M. W. 159. 94) and sodium chloride (M. W. 485). Perhaps by using other salts a relationship between molecular weight and solubility might be found.

If the molecular weight of a soluble salt is high, then the amount of this salt that will go into solution at 100°C will also be high.

Experiment

Apparatus : The following dehydrated, soluble salts were used :

1.	Calcium iodide	CaI_2
2.	Cupric chloride	$CuCl_2$
3.	Cupric sulphate	$CuS0_4$
4.	Ferric bromide	$FeBr_2$
5.	Ferrous chloride	$FeCl_2$
6.	Potassium carbonate	K_2C0_3
7.	Potassium dichromate	$K_2Cr_20_7$
8.	Sodium carbonate	Na_2C0_3
9.	Sodium chloride	$NaCl$
10.	Sodium dichromate	$Na_2Cr_20_7$
11.	Sodium chromate	Na_2Cr0_4
12.	Sodium nitrate	$NaN0_3$
13.	Ammonium chloride	NH_4Cl
14.	Ammonium sulphate	$(NH_4)_2S0_4$

Procedure: 1C0 grams of dehydrated salt was weighed out on paper. From this stock of 100 grams small amounts of salt were added to 100 ml of 80°C distilled water. The solution was stirred until the salt dissolved and then more salt was added. Salt was first added to water at 80°C to speed the process while maintaining a precaution against adding too much salt. When the salt began to dissolve very slowly in the water, the temperature was raised to 100°C and the solution stirred. If all the salt dissolved, small amounts 0.1 grams or less, were added. This step was repeated until a few crystals remained after stirring for five minutes. The remaining salt on the paper was weighed and recorded. This process was repeated for all the salts.

The solubility product is the amount of salt that will go into solution at a particular temperature. In our experiment the temperature was 100°C. The S.P. is calculated by finding the number of gram moles dissolved in one liter of water.

$$\text{S. P.} = \frac{10 \text{ mole}}{\text{G.M.W.}} \times \frac{\text{grams dissolved salt}}{\text{1 liter of water}} = \frac{\text{moles}}{\text{liter}}$$

Results

Results are tabulated below :

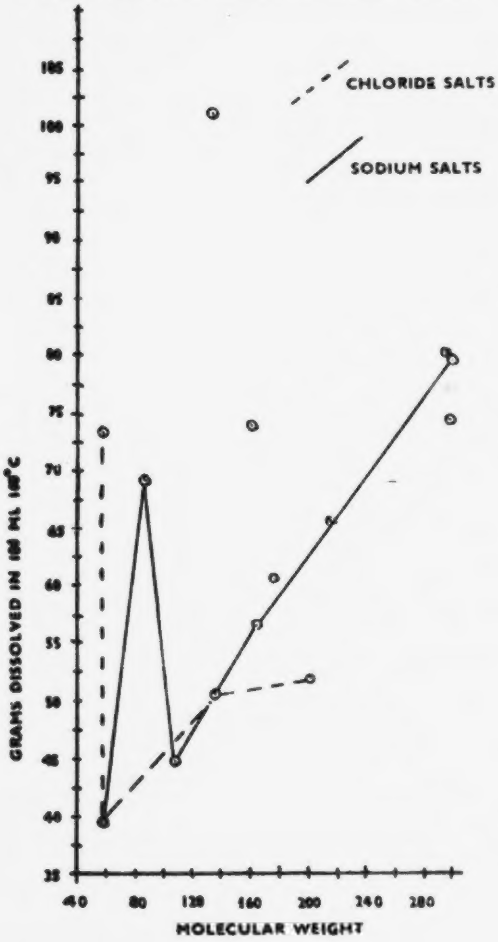
A) Temperature kept at 100°C.
B) Sheets of weighing paper weighed about 1.0 gr.

Table 1

No.	Salt	(Salt + Paper) First Weighing	(Remaining Salt + Paper) Second Weighing	Salt Dissolved Difference
1.	CaI_2	103.2 gr	23.1 gr	80.1 gr
2.	$CuCl_2$	100.9	50.0	50.9
3.	$CuS0_4$	102.8	28.9	73.9
4.	$FeBr_2$	101.5	36.2	65.3
5.	$FeCl_3$	101.3	49.0	52.3
6.	K_2C0_3	106.2	45.8	60.8

No.	Salt	(Salt + Paper) First Weighing	(Remaining Salt + Paper) Second Weighing	Salt Dissolved Difference
7.	$K_2Cr_2O_4$	97.9	23.1	74.8
8.	NaCl	100.7	60.9	39.8
9.	Na_2CO_3	101.2	36.4	44.8
10.	$Na_2Cr_2O_7$	99.6	20.2	79.8
11.	Na_2CrO_4	100.3	43.4	56.9
12.	$NaNO_3$	103.8	34.5	39.3
13.	NH_4Cl	96.9	23.3	73.6
14.	$(NH_4)_2SO_4$	98.3	1.2 Not enough	97.1
		10.9	7.0	3.9
				101.0

I. GRAMS DISSOLVED VERSUS MOLECULAR WEIGHT



II SOLUBILITY PRODUCT VERSUS MOLECULAR WEIGHT

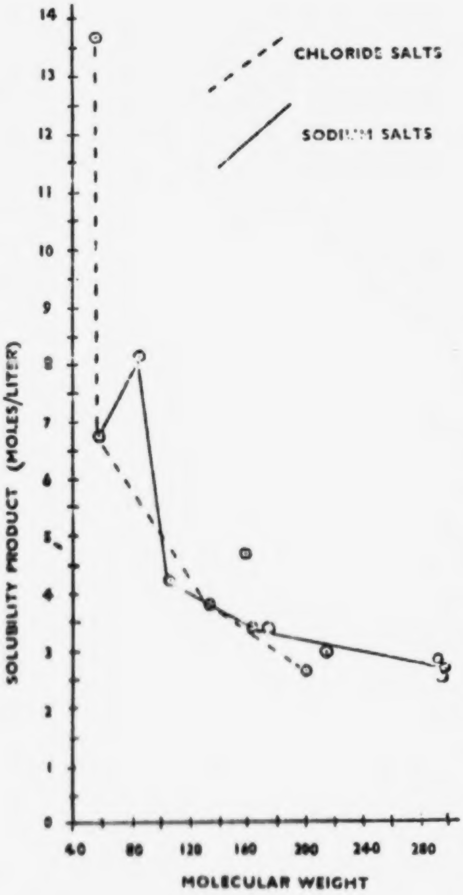


Table 2.

No.	Salt	Molecular Weight	Grams Dissolved	Solubility Product
1.	NH_4Cl	54	73.6	13.61 moles/litre
2.	$NaCl$	58	39.8	6.80
3.	$NaNO_3$	85	69.3	8.15
4.	$NaCO_3$	106	44.8	4.23
5.	$(NH_4)_2SO_4$	132	101.0	7.65
6.	$CuCl_2$	135	50.9	3.77
7.	$CuSO_4$	159	73.9	4.64
8.	Na_2CrO_4	162	56.9	3.45
9.	K_2CO_3	174	60.8	3.48
10.	$FeCl_2$	200	52.3	2.61
11.	$FeBr_2$	216	65.3	3.02
12.	CaI_2	294	80.1	2.76
13.	$K_2Cr_2O_7$	298	74.8	2.53
14.	$NaCr_2O_7$	298	79.4	2.66

SODIUM SALTS

Table 3

Salt	Molecular weight	Grams Dissolved	Solubility Product
$NaCl$	58.5	39.8 gms	6.80 moles/litre
$NaNO_3$	85.0	69.3	0.15
Na_2CO_3	105.0	44.8	4.23
Na_2CrO_4	162.0	56.9	3.45
$Na_2Cr_2O_7$	298.0	79.4	2.66

CHLORIDE SALTS

Table 4

Salt	Molecular Weight	Grams Dissolved	Solubility Product
NH_4Cl	54.0	73.6	13.61 moles/litre
$NaCl$	58.5	39.8	6.80
$CuCl_2$	135.0	50.9	3.77
$FeCl_2$	200.0	52.3	2.61

Discussion

Possible errors in conducting this experiment could have resulted from improper weighing or adding too much salt. Some extra salt had to be added to know when the saturation point was reached. But the same amount of crystals might not have been added in excess, thus causing a minor error. However, it is judged that this error is not large enough to significantly effect our results. It is evident from the results that the molecular weight is not related to the amount of salt dissolved.

When comparing the solubility product to the molecular weights an irregular curve is obtained. A curve might be fitted to the data showing that high solubility usually occurs in the low molecular weight salts, and that low solubility occurs in the larger molecular weight salts. But this curve is not defined well enough to accept this hypothesis with the data presented here.

The interpretations presented so far refer to a random selection of salts. Perhaps salts that have a common ion will yield some useful data. In our sample we have five salts with a common positive ion–sodium. They are NaCl, Na_2CO_3, $Na_2Cr_2O_7$, $NaCrO_4$, and $NaNO_3$. There are four salts with a common negative ion – chloride. They are $CuCl_2$, NaCl, NH_4Cl, and $FeCl_3$. The data for these salts are listed separately in tables 3 and 4.

In common ion salts, no trend is prominent when comparing the amount dissolved to the molecular weight. But by plotting the solubility product versus molecular weight it would appear that molecular weight does effect the solubility product since a relatively smooth curve was obtained. With our limited data for salts with a common ion we can say that the solubility product for them is inversely proportional to molecular weight of the salt.

Summary

An experiment was conducted to test the hypothesis that the amount of a salt which will go into solution depends upon its molecular weight. The data obtained was so irregular that the hypothesis could not be supported. However, an alternative hypothesis was formulated which stated that the solubility of a salt depends upon its molecular weight. The data, in part, supports the hypothesis. It was found, however, that the data is insufficient to to make a categorical statement in this regard and further investigation of this point is needed.

PERCENTAGE OF SAND IN SOIL

Introduction

Soil is the covering over most of the land surfaces of the Earth. It is made up of rock and mineral particles of many sizes mixed with living things and their remains. Soil is made up of three main ingredients: sand, clay and humus (organic material). Most soils are not pure sand, clay or silt, rather, they are mixtures of all the particles found in the soil. Such mixtures are called loam. To be considered a sandy soil, the soil must be at least half sand. The composition of the soil helps to determine its fertility. Sandy soil is not good for growing plants because it does not hold water well. Clay soil is not good either, for it is packed so tightly that not enough air can reach the plant roots. A fine loam, with a large amount of silt and humus, is usually the best kind of soil.

What is the sand composition in the various types of soil around the village? And what types of plants grow in each sample and how plentiful are they?

Experiment

Procedure: Samples of soil were collected from the beach, the river delta, paddy field, clay field, and the school compound. The types and numbers of plants growing in each area that a sample was collected from were recorded. 500 grams of one sample was placed in a large bucket. The bucket was filled with clear water; the soil and water were stirred to dissolve clay out of the oil. After the solution settled for two, minutes the liquid was decanted off. These operations were repeated until the water was decanted clear. Large stones, broken glass and other objects were picked out of the remaining sand. The sand was filtered, dried and weighed The weight of the sand was divided by the weight of the original sample to find the percentage of sand in the soil. This procedure was repeated for each sample.

Results

Results are tabulated below:

Trial Type	Weight of sample	Weight of sand	Percentage of sand
Beach	505 gr	500 gr	99%
River Delta	498	339	68%
Paddy Field	500	220	43%
Clay Field	503	148	28%
School Compound	505	198	36%

Questions

1. Which type of soil has the highest percentage of sand? Which type of soil has the lowest percentage of sand?

2. On which type of soil do the most different types of plants grow? On which type of soil do the fewest types of plants live?

3. On which type of soil do the greatest number of plants live? The least?

4. Do different types of plants prefer particular types of soil? If so, which plants prefer which soil?

5. Are some plants unaffected by the type of soil on which they grow? Do they grow equally well on all types of soil?

6. Does sand play an important role in making good soil?

7. How can you determine the percentages of the other major soil constituents?

FALLOUT

Introduction

Any dust that settles from the atmosphere can be called 'fallout'. People often associate fallout only with radioactive dust produced by nuclear bombs that are tested in the atmosphere. However, atmosheric fallout may be due to many causes. The smoke from chimneys of big factories and industries, volcanoes, chulas in our homes, and the transportation of particles by wind contribute to fallout.

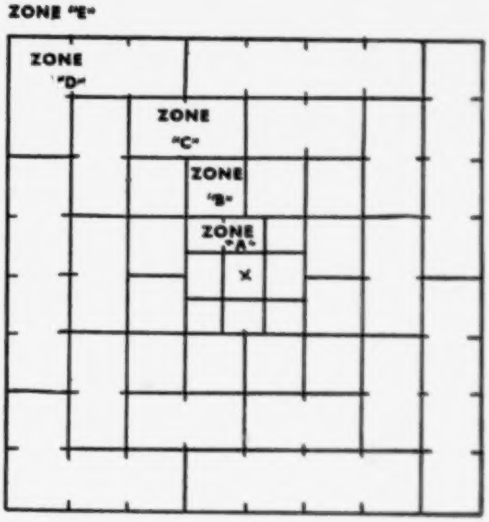
We usually regard dust in the air as undesirable, but experiments have shown that dust particles are an essential element in the formation of clouds. Droplets of moisture form around dust particles and the droplets form rain and other forms of precipitation. The beauty of the sunset is due to scattering of sunlight by fine dust particles.

The smoke given off by chulas in the home is made mainly of carbon particles. These particles coat the bottom of the cooking pans and turn them black. Some particles fly past the pans and settle about the room. Some particles, which we cannot see, may not settle for a long time. The fire may give air currents with much energy so that the particles will fly high and far. But the weight of the particle may determine the distance which it will travel. Perhaps the relationship between particle size and distance the particle travels can be demonstrated in the classroom by using an ammonium dichromate "volcano." If the size of the particle given off by the "volcano" is increased, then the distance it travels will decrease.

Experiment

The "volcano" is made from a small ghee cup supported by heavy wire one inch above a large cleared area (earthen floor). The cup is filled with 250 grams of ammonium dichromate, $(NH_4)_2Cr_2O_7$. A two inch piece of magnesium is placed half way into the $(NH_4)_2Cr_2O_7$. The area around the "volcano" is marked off as shown in figure 1.

FIGURE No. 1 "VOLCANO" AREA LAY OUT



ZONE "A"	9	TWO INCH SQUARES
ZONE "B"	12	THREE INCH SQUARES
ZONE "C"	10	2-THREE INCH SQUARES
ZONE "D"	7	4-THREE INCH SQUARES
ZONE "E"		REMAINING AREA

The magnesium ribbon is ignited and the volcano is observed until it burns out. The size of the particles and the time they come off in relationship to the time of eruption is noted. The members of the science club collected, counted, and weighed the ashes in the area they were responsible for. The data was collected and tabulated.

Formula for the reaction is:

$$(NH_4)_2Cr_2O_7 + \text{HEAT} \longrightarrow 2NH_3 + H_2O + 2CrO_3$$

Results

Results are tabulated below:

DATA

Weight of $(NH_4)_2Cr_20_7$and ghee cup. A .. ..
Weight of ghee cup. B...............
Weight of $(NH_4)_2$ Cr_20_7. C...... ....
Total weight of ashes collected. D............ .....
Difference in "C" & "D". E ....

Two inch squares – Zone A

Square Number	Number of Particles	Weight of Particles	No. of Particles Sq. Inch	Wt. of Particles Sq. Inch	Weight Particles
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
TOTAL					

Three inch squares – Zone B

Square Number	Number of Particles	Weight of Particles	No. of Particles Sq. Inch	Wt. of Particles Sq. inch	Weight Particles
10.					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					
21.					
TOTAL					

Three inch squares–Zone C

Square Number	Number of Particles	Weight of Particles	No. of Part./Sq. Inch	Wt. of Part./Sq. Inch	Weight/Particles
22.					
23.					
24.					
25.					
26.					
27.					
28.					
29.					
30.					
31.					
TOTAL					

Three inch squares–Zone D

Square Number	Number of Particles	Weight of Particles	No. of Part./Sq. Inch	Wt. of Part./Sq. Inch	Weight/Particles
32.					
33.					
34.					
35.					
36.					
37.					
38.					
TOTAL					

Remaining area–Zone E

Square Number	Number of Particles	Weight of Particles	No. of Part./Sq. Inch	Wt. of Part./Sq. Inch	Weight/Particles
39.					
40.					
41.					
42.					
43.					
44.					
TOTAL					

Zone	No. of Part./Sq. Inch	Wt. of Part./Sq. Inch	Weight/Particles
A.			
B.			
C.			
D.			
E.			

Questions

1. What is the amount of ash found? How much ash was expected. Explain the difference.

2. When were the larger particles given off—during the first of the eruption or near the end? Were the large particles located near the centre or far? Were they evenly distributed? What is the explanation for this?

3. When were the smaller particles given off—during the first or later part of the eruption? Are most of the small particles located near the centre? Explain.

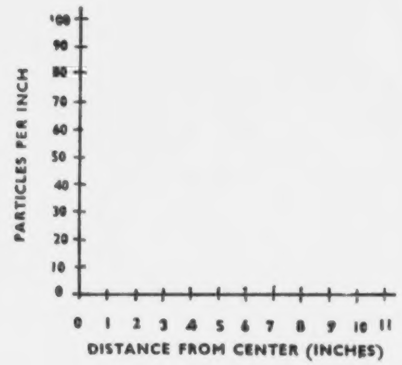
4. Is the distribution of particles equal all the way around the centre? If so, why? If not, why?

5. Does the data agree with the hypothesis? In which way does it agree and which way does it not agree?

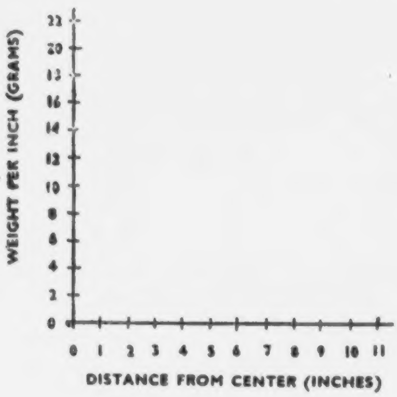
6. Are there other possible hypotheses to explain the results of our data? How can they be checked?

7. Could errors be detected in the experiment? Could they be corrected?

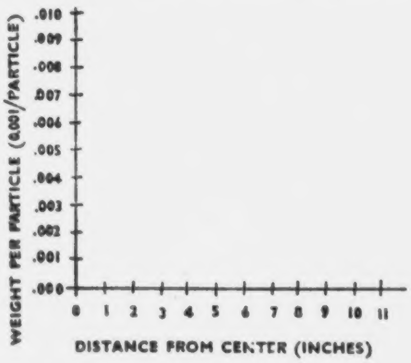
I PARTICLES PER INCH VERSUS DISTANCE FROM CENTER



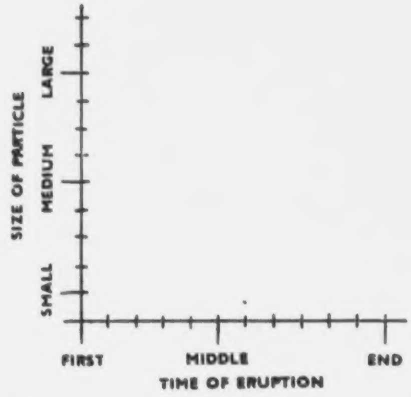
II WEIGHT PER INCH VERSUS DISTANCE FROM CENTER



III WEIGHT PER PARTICLE VERSUS DISTANCE FROM CENTER



IV SIZE OF PARTICLE VERSUS TIME OF ERUPTION



HINTS FOR INVESTIGATIONS IN CHEMISTRY

1. How many grams of water can be absorbed per grain of blotting paper newspaper, and book paper?

2. What affect does the amount of surface area have on the rate at which a substance dissolves in a liquid? Try dissolving a large piece of material; then try breaking the material into smaller pieces. (Brown sugar can be used.)

3. Will all chemicals dissolve in the same amounts of water at a given temperature?

4. What effect has the rate of evaporation on the formation of crystal. Make a supersaturated solution of salt. Pour some into several jars. Suspend a string into the centre of the salt solution in each jar. Control the rate of evaporation by using jars with different size openings.

5. What effect does temperature have on the formation of crystals? Make a supersaturated solution of alum or epsom salt. Pour some of the solution on a warm piece of glass. Pour another sample of the solution on a cold piece of glass.

6. Can you determine the temperature at which different chemicals in solution will crystalize?

7. What is the effect of increasing the amount of current on the rate at which water breaks up during electrolysis? Will electrolysis work with both A.C. and D.C. current?

8. Why does lime water turn milky when exposed to carbon dioxide? Make lime water by mixing a teaspoon of hydrated lime with 500 ml of water. After the lime sinks to the bottom of the bottle, filter the liquid and then screw the lid down tightly.

Does the air around us contain carbon dioxide? Place a dish of lime water on the table. Observe later. If carbon dioxide is present, there should be a scum on the water.

9. What liquids and other materials contain chlorine? Mix one gram of starch with 60 ml of water. Bring the water to a boil. Dissolve a very small amount of potassium iodide in the mixture. Dip strips of filter paper or blotting paper in the mixture and dry them. A strip will turn blue in the presence of chlorine.

10. How do various ions affect the color of borax when heated in a hot flame? Make a small loop, wrapping the end of a piece of nichrome wire around the end of a sharp pencil. Insert the other end of the wire into a piece of cork. The cork will serve as a handle. Heat the wire loop and dip the loop into melted borax to form a bead. Touch the bead to the chemical to be tested and and then heat the bead in a very hot flame You can use a blow pipe with a spirit lamp. The color of the bead when cold compared to the color when the bead hot is used to determine the metal.

11. Test the hardness of water around the area in which you live. Make a test solution by dissolving about a gram of soap flakes in about twenty cc of spirit, acetone, or methyl alcohol. Filter the solution. Test the unknown sample by filling a jar half full of water. Add about ten drops of your soapy test

solution to the water. Cover and shake the jar. The amount of foam indicates the degree of hardness; very hard water makes little foam. Test distilled water and rain water also.

12. What kind of soap or detergent gives the most suds? Fill test tubes with different kinds of detergents and soaps. Add oil drops. Which detergents and soaps mix with oil? Add one part lime water to two parts solution. Shake the test tube and note the amount of foam compared with other soap products.

13. Find the pH of soil from different locations in your village. Titrate the soil with a base or acid of known strength. What other common chemical test can be done on soils?

14. Can you collect the vapors from a candle flame and change them into a solid? Conduct the vapors from the flame and into a cold bottle by using bent glass tubing.

15. How small is a molecule? Dissolve a gram of potassium permanganate in 100 cc of water. This gives a solution of 1 to 100. The color is due to $KMnO_4$ molecules moving around in the water. Remove 10 cc of this solution and add to 90 cc of fresh water You now have a solution of 1 to 1000. Can you see the color? Repeat this with several additional bottles of water. Be sure always to take your colored solution from the bottle containing the weakest solution. Can you still see the molecules after you have diluted the solution to 1 to a million parts?

16. How can rusting of iron be prevented? If rust is iron reacting with oxygen in very slow burning, could you coat nails with different materials to prevent the oxygen from reaching the iron? Will rust occur without moisture?

17. Is there water in petrol, spirits, vinegar, and sweet oil? Copper sulphate is a test for water. Heat some crushed $CuSO_4$ crystals in a test tube until they form a white powder. You have removed all the water from the salt. If you add this powder to a small amount of liquid that does not contain water, the crystals will not change. If water is present the crystals will turn blue.

18. Can you make your own photographic paper and take photographs with it? Mix silver bromide with gelatin and spread on a heavy paper. Fasten the paper to a piece of plywood and place it in the sunlight. Place some object such as a leaf on the paper and then cover with a piece of glass. In order to fix the print after the paper has turned a dark violet, soak the paper in a solution of hypo for about ten minutes.

19. What liquids are colloids? Shine a small beam of light through the test liquid. If the liquid is a colloid, large particles reflect light and the light beam can be seen. Try shampoos, hair oils, petrol and other liquids.

20. How can you tell different fabrics apart? Burn small pieces of the material in the flame of a spirit lamp. Note and record characteristics of the flame, the smell, and the remaining ash after burning. A chemical test can be devised by using sodium hydroxide solution and then a hydrochloric acid slution on a small sample.

21. Litmus paper can be made by boiling strips of red cabbage and let stand for about a half hour. The liquid

can then be used as an indicator. You can soak duplicator paper or filter paper strips in the color water and let dry. Try making other indicators by using blueberries, different flowers and other plants and vegetables.

22. What is the relationship between the distance between electrodes and the amount of current that passes in an electrolytic solution.

23. Which acid is the best conductor? Does the conductivity depend upon the H^+ concentration? What molar solution of NaCl provides the best conductivity?

24. What is the concentration of H^+ ions (pH) for the same solution of H_2SO_4, HCl, HNO_3 carbonic acid, and oxalic acid?

Biology

EFFECT OF EXERCISE ON METABOLISM

Introduction

Metabolism is the sum of all the chemical changes taking place within the human body. One of the major components of this process is the energy production which takes place within individual cells. Oxygen is taken into the cell and used to produce energy. One by-product of this process is the production of CO_2, a waste product which must be eliminated from the body. Carried by individual red blood cells to the lungs, CO_2 is eliminated from the body through a gas exchange process within the Avcoli. Carbon dioxide is deposited and the red blood cells carry oxygen back to the rest of the body. If the metabolism of the body is increased, more CO_2 is produced and hence the CO_2 concentration in the blood increases. This concentration is sensed by a mechanism located within the brain by which involuntary control of the breathing rate is regulated. It would seem natural that the respiratory process then would have to be speeded up to allow additional oxygen to be brought to the cells as well as the elimination of the excess CO_2 produced by the cellular respiratory process.

The increase in rate of respiration is commonly observed when an individual is working vigorously. Moreover, the body becomes overheated and the sweat glands begin to function to eliminate the excess heat through evaporation cooling – cooling of the skin area and thereby of the dilated blood vessels near the surface.

If under conditions of vigorous exercise there is indeed an increased metabolic rate, then there should also be an increased amount of carbon dioxide being exhaled. Because of the previous observations, one would think that this would be so. As a consequence of this it is predicted that an increase of the exercise state of the body should likewise show an increase in the rate of CO_2 being eliminated from the body along with the subsequent increase in the surface (skin) temperature, the rate of breathing and the activity of the sweat glands.

Experiment

Subjects : The subjects were the 48 members of one science class consisting of 24 males and 24 females ranging in age between 14-16 years old. Half of the boys and half of the girls were vegetarians. All subjects were judged to be in good health.

Apparatus : The apparatus consisted of 12 identical 250 ml flasks and 12 glass delivery tubes 20 cm in length and 3mm interior diameter. A 5% solution of phenophthalein was used as the indicator and the titration agent was a O.O4% solution of NaOH.

Procedure: Before the subjects appeared, the apparatus was set out and prepared. In each flask the following chemicals were put : 100 ml H_2O (pH of H_2O was controlled at 7), 5 drops of the phenolphthalein indicator solution and enough NaOH so that each solution turned slightly pink; all flasks were judged to be the same color.

The students were instructed to take their meals between the hours of 7:00 and 8:00 on the mornings of testing. Upon their arrival in the classroom (first period), they were instructed to take rest for 15 minutes. After resting, the subjects were randomly divided into two groups. Each group contained 6 vegetarian boys and 6 non-vegetarian boys, 6 vegetarian girls and 6 non-vegetarian girls. Immediately following this procedure Group I was tested.

Testing consisted of exhaling normally for one minute through the delivery tube into the 250 ml flask containing the previously described solution. After one minute the solutions were taken from the subjects and tested for CO_2 content in the following manner: Drops of NaOH were placed into the slightly acidic solution (the combination of CO_2 and water yields a weak solution of carbonic acid); enough drops are added to bring the solution back to its original pink color; the number of drops needed are counted and noted; it is known that one drop of O.O4% NaOH is equivalent to 10 micromoles of CO_2; hence micromoles of CO_2 can be noted.

Group I then undergoes five minutes of vigorous (running in place 168 steps/minute) exercise and upon completion is again tested for CO_2 content.

Group II is made to do vigorous exercise for 5 minutes immediately following the 15 minute rest period and is then tested for CO_2 content.

Following this, they are again allowed a 30 minute rest period at the end of which they are tested for CO_2 content, this being considered the rest condition. The next morning the same test procedures are followed, but the group conditions are reversed. That is, Group I goes through Group II's first day procedure, and Group II likewise follows Group I's first day procedure.

It should be noted that the data are kept separately by group and by whether the subject is a vegetarian, non-vegetarian, male or female. The data will be combined if there are no differences found between groups except as the results of the experimental and control conditions.

Results

The obtained data are given below. The data are stated in micromoles of CO_2 produced.

Table 1

Data For Each Subject

	Subject	Diet	Sex	Exercise (Micromoles)	Rest (Micromoles)	Difference (Micromoles)
GROUP I	1	V	M	161	127	34
	2	V	M	176	126	50
	3	V	M	137	99	38
	4	V	M	145	111	34
	5	V	M	159	120	39
	6	V	M	193	121	72
	7	V	F	129	86	43
	8	V	F	150	114	37
	9	V	F	199	105	95
	10	V	F	168	78	90
	11	V	F	132	87	45
	12	V	F	130	99	31
	13	NV	M	179	133	46
	14	NV	M	181	121	60
	15	NV	M	156	98	58
	16	NV	M	200	111	89
	17	NV	M	190	100	90
	18	NV	M	145	101	44
	19	NV	F	141	102	39
	20	NV	F	154	100	54
	21	NV	F	149	89	60
	22	NV	F	144	95	49
	23	NV	F	140	72	68
	24	NV	F	135	89	46

	Subject	Diet	Sex	Exercise (Micromoles)	Rest (Micromoles)	Difference (Micromoles
GROUP II	25	V	M	149	104	45
	26	V	M	192	117	75
	27	V	M	179	121	58
	28	V	M	177	117	60
	29	V	M	156	109	45
	30	V	M	181	100	81
	31	V	F	121	84	37
	32	V	F	145	95	50
	33	V	F	129	96	33
	34	V	F	131	73	58
	35	V	F	140	77	63
	36	V	F	130	87	43
	37	NV	M	177	127	50
	38	NV	M	145	109	36
	39	NV	M	140	109	31
	40	NV	M	190	121	69
	41	NV	M	171	113	58
	42	NV	M	158	103	55
	43	NV	F	131	87	44
	44	NV	F	154	86	68
	45	NV	F	153	90	63
	46	NV	F	139	99	40
	47	NV	F	138	91	47
	48	NV	F	127	83	44

Table 2

Averages

	Rest	Exercise
Male		
Vegetarian	114	167
Non-Vegetarian	112	169
Female		
Vegetarian	91	142
Non-Vegetarian	90	142

Table 3

Data In Terms Of Averages – Combining – Vegetarian & Non–Vegetarian Data

	Rest	Exercise	Difference
Male	113	168	55
Female	90.5	142	51.5

Table 4

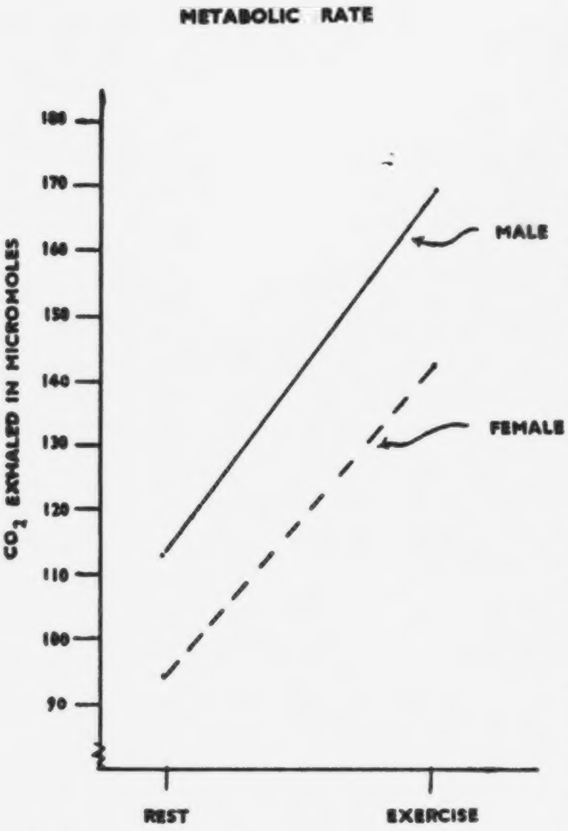
Sum Of Micromoles Of CO_2 For Each Group

	Exercise	Rest	Difference
Group I	3753	2483	1270
Group II	3653	2399	1254
Differences	100	84	

Table 5

Data Stated In Averages Of Micromoles Of CO_2

	Exercise	Rest	Difference
Group I	156.5	103.5	53.0
Group II	152.5	100.0	52.0
Differences	4.5	3.5	



The raw data for the first day are given in Table I . Table II gives the rest and exercise averages for both days for males and females split into vegetarian and non-vegetarian groups. From this table vegetarian and non-vegetarian data do not differ significantly. Table III combines the vegetarain and non-vegetarian groups and gives averages for the independent variable for male and female subjects. From this table one can conclude that there are large differences between male and female metabolic rates, but that increments due to the experimental condition are fairly constant. Table IV gives the summation of the raw data for Group I and Group II for the first day, and Table V gives the averages. It is apparent from scrutiny of this table that the group conditions did not influence the data.

Discussion

After examining the data we are forced to conclude that there are no differences in metabolic rate in vegetarians and non-vegetarians and that there are large differences between male and female metabolic rates. The action of the independent variable is dramatic and consistent throughout all subjects over all trials.

It has likewise been noted that as the exercise continued the subjects' breathing rates increased and were fastest at the end of the exercise period. Likewise, the subjects perspired a great deal, and we must conclude that this is due to an increased amount of heat produced in the body which must likewise be due to increased oxidation and hence an increased metabolic rate. It is apparent that an increase in exercise results in an increase in both the breathing rate and the overall amounts of CO_2 eliminated from the body. This, then, poses the question about the increments of exercise necessary to yield a certain increment in CO_2 exhaled per unit time. Further information is necessary using various conditions of exercise to demonstrate this relationship. Likewise, what is the relationship between the amount of heat and sweat produced?

It would seem that the breathing rate should be controlled by some factor which senses the amount of CO_2 in the blood and hence the amount of metabolic activity going on within the body. The question raised here is whether there is another way that metabolic rate can be increased without exercise.

We notice the same phenomena when people are frightened. That is, there is an increased breathing rate as well as increased perspiration, though perhaps not in the same quantity. This would indicate that metabolic rate can be increased without exercise and is also controlled by some factor in addition to the CO_2 content of the blood. The questions then raised would be concerning the effect of increasing breathing rate artificially (perhaps by the use of hormones) on the metabolic rate.

During this experiment, the subjects were observed to perspire a great deal when they were exercising. If, then, perspiration were increased artificially (not caused by exercising) would this necessitate an increase in the metabolic rate? And if so, what would its controlling mechanism have to be?

Still another experiment is suggested by our results. If the subject were simply instructed to breathe faster (hyperventilation) and not exercise, could we observe an increase in the amount of CO_2 produced after varying amounts of time of hyperventilation. These conditions would raise the breathing rate without significantly increasing exercise and without introducing hormones into the bloodstream, and it might prove interesting to observe the effects of this type of condition.

It would seem, therefore, that we have more than one index of metabolic rate. Metabolic increases are indicated oy a syndrome of observable phenomena—increased body heat, increased CO_2 produced per unit time, increased perspiration and increased breathing rate. It has been suggested that these four measures be manipulated independently of the exercise condition and the effects be observed. Likewise, there is need for a clearer delineation of the exercise variable, meaning varying amounts of exercise must be given to subject and their metabolic rate indicators must be measured. It is also clear that more information about metabolic rate is needed in connection with certain subject variables such as age, weight, muscle tone, and sex.

Summary

An experiment was conducted to observe the effect of vigorous exercise on the metabolic rate of 24 male and 24 female students ranging from age 14 to 16 years old. The subjects were divided according to diet and sex and their data was tabulated separately. It was found that under conditions of exercise, more CO_2 was produced than under the control rest condition. Likewise, it was found that males have a higher metabolic rate than females and that there are no differences due to vegetarian or non-vegetarian diet.

It was suggested that the exercise and subject variables be more clearly delinated and that the indicators of metabolic rate (perspiration, increased breathing rate, CO_2 produced, and body heat) be examined independent of the exercise condition..

EFFECT OF TEMPERATURE ON DIFFUSION RATE

Introduction

When a liquid is heated it has been noticed that the liquid has a tendency to increase its activity rate. Convection currents are an example of this. In diffusion, solute and solvent particles move through the membrane. The size of the particle that goes through depends on the number and size of the openings in the membrane. It might also depend upon the activity of the molecule.

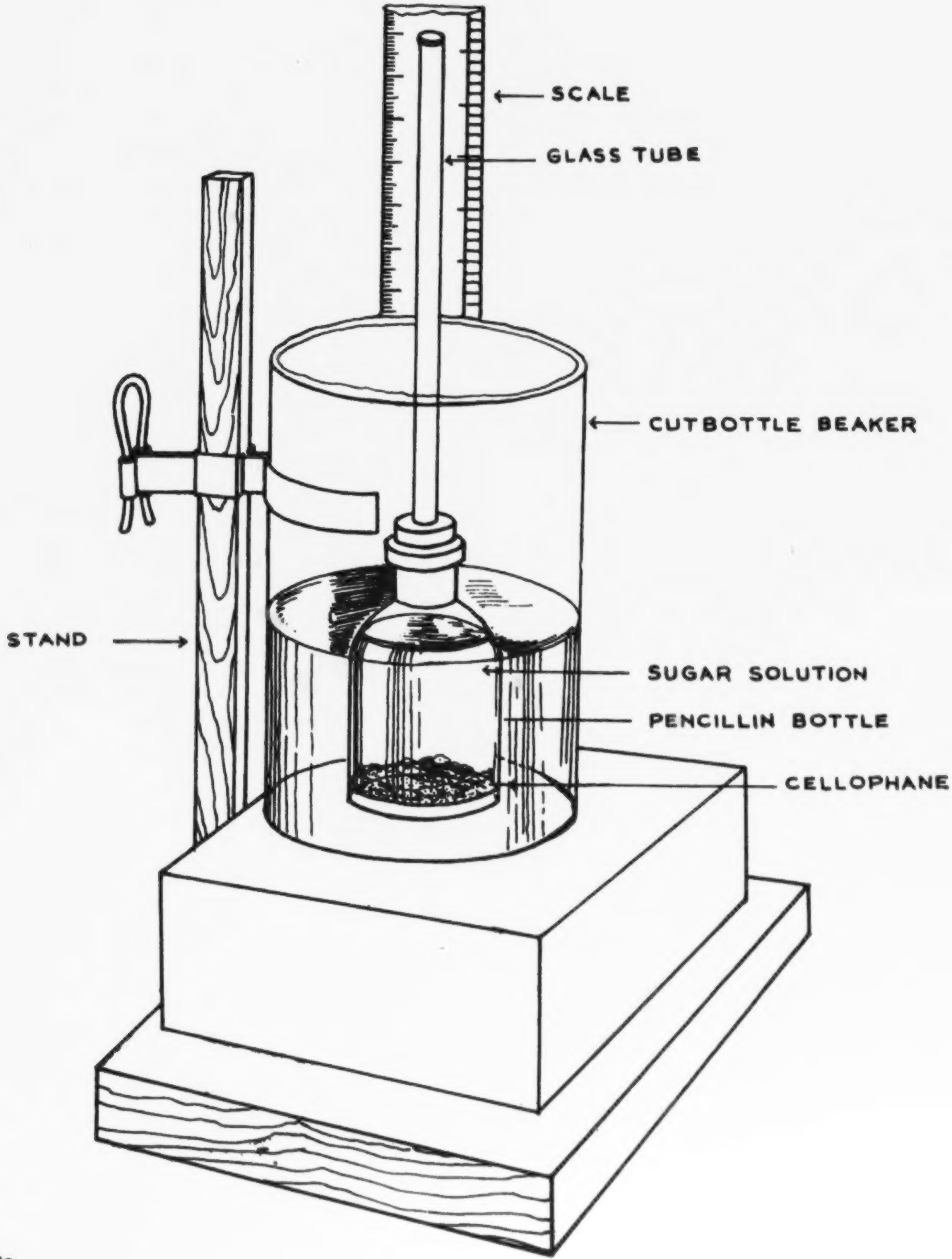
If this is so, the liquid can be heated, and the particles then should move through the membrane at a faster rate.

Experiment

Procedure: To test this hypothesis a piece of cellophane was tied to the underneath side of a bottomless medicine bottle. This bottle was filled with sugar solution. Its mouth was closed by a one-hole rubber stopper which contained a glass tube. The glass tube filled about 1/3 full of the sugar solution and a piece of graph paper was attached to it to act as a scale.

DIFFUSION OF LIQUIDS

THROUGH A MEMBRANE


SCALE
GLASS TUBE
CUTBOTTLE BEAKER
STAND
SUGAR SOLUTION
PENCILLIN BOTTLE
CELLOPHANE

This assembly was immersed deep enough into a beaker containing water to completely immerse the membrane. A thermometer was placed in the water solution to record temperatures. The level of sugar solution in the glass tube was noted thus beginning the experiment. The rate of diffusion was noted at room temperature and then the water was heated to record the rates of diffusion at higher temperatures. Each observation was made after 30 minutes in the heated water solution.

Results

The results are given below:

Trial	Temperature °C	Initial Reading cm	Second Reading cm	Change cm
1	28.0	3	5	2
2	27.5	4	6	2
3	34.5	3	6	3
4	35.0	5	7	2
5	39.5	4	7	3
6	40.5	5	9	4
7	45.5	4	9	5
8	45.0	3	8	5
9	50.5	4	9	6
10	49.0	5	10	5

Trial time = 30 minutes

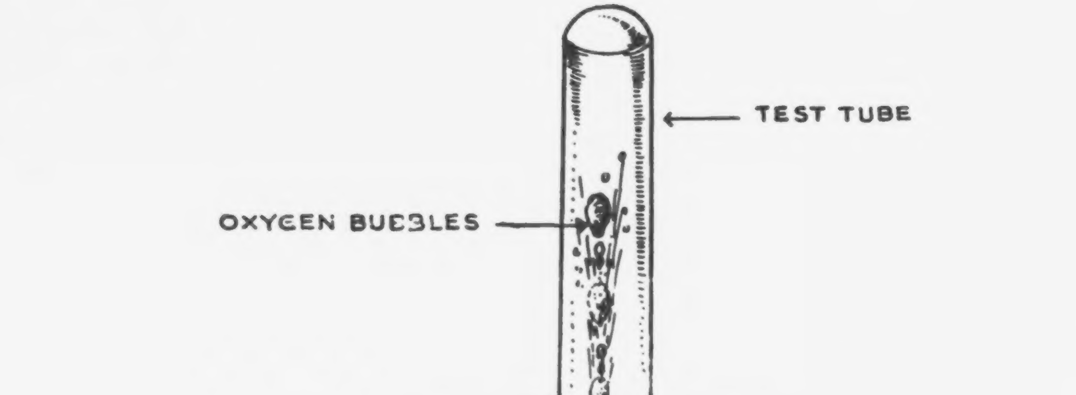
Discussion

Rates of diffusion increasad as temperature increased and this probably due to the increase in activity of molecules. It would oppear that given increments in temperature yield constant increments in diffusion rate. It would be sood, however, if the study were extended to further investigate this linear relationship.

Summary

An experiment was conducted to observe the rate of movement of particles through a membrane at different temperatures. Diffusion through a membrane separating a sugar solution from water was noted by the level rise in the sugar solution at different temperature increases. It appeared to the experimentor that equal incrementsin stemperature yield constant increment in diffusion rates. However further study would be required to demonstrate this phenomenon.

PHOTO SYNTHESIS EXPERIMENT


TEST TUBE
OXYGEN BUBBLES
BEAKER
FUNNEL
POND WATER
HYDRILLA
OR ELODIA PLANTS

EFFECT OF PROLONGED LIGHT ON PLANT GROWTH

Introduction

It is a common observation that most plants grow best where there is plenty of light. This may be because these plants can produce more food and hence grow taller and healthier. In this regard it would seem that light then is necessary for food production and hence photosynthesis. If large amounts of light are required for photosynthesis then increments in light may yield increments of photosynthetic activity.

Experiment

Subjects: The subjects of this experiment were Hydrilla plants.

Apparatus: An apparatus was designed to catch the oxygen produced as the results of photosynthesis (see diagram). If consisted of a funnel cut from the top of a squash bottle and a test tube which fit over the funnel end.

Procedure: This assembly was submerged in a beaker full of water and the Hydrilla plants were placed under the funnel. The test tube was filled with water and the oxygen produced by the plant would displace this water and provide a convenient measuring device A 60 watt Bajaj light bulb was placed within 5 cm of the plant and remained on for one week. After every 24 houe period the amount of oxygen evolved wes noted, recorded and tested by absorption in alkaline pyrogallol (pyrogallic acid dissolved in alcohol).

Results

The data are presented below:

Day	Hours of Exposure	Total Amount of 0_2 Evolved	Amount of 0_2 Evolved on Each Day
1	24	11	11
2	48	22	10
3	72	32	11
4	96	42	10
5	120	51	9
6	144	60	9
7	168	67	7

The unnatural condition of constant bright light seemed to have a bad effect on the rate of photosynthesis.

Questions

1. What can you conclude from this study?

2. Are there any variables which have been left uncontrolled? Which ones? How could you control this study better?

3. How should the procedure be better controlled?

4. Will the intensity of light have an effect on the rate of photosynthesis when the periods of exposure are restricted to a normal duration for a plant?

5. Is there an optimum period of light exposures per day for a plant?

EFFECT OF pH ON ENZYME ACTION

Digestion in the stomach takes place in an acidic medium because of the stomach's secretion of hydrochloric acid. In the mouth there is neither an alkaline nor an acidic medium. Here the digestion of starches begins with the enzyme ptyalin.

If the digestion of starch by ptyalin takes place in the acidic medium then we could assume that it would continue once the substance reaches the stomach. However, if under acidic conditions ptyalin will cease its activity, then we can infer that the breakdown of starches into sugar by ptyalin is completed when the food enters the stomach.

If the pH of a starch solution containing ptyalin is changed from neutral, there may be a difference in the amount of starch converted to sugar.

Experiment

Procedure: Three test tubes were used and 3 to 5 cc of saliva was added to each. One test tube had a small amount of dilute hydrochloric acid added to it and another had a small amount of dilute sodium hydroxide added to it. The other test tube is allowed to remain in its normal pH state. About 5 cc of starch solution was added to each test tube and the test tubes were allowed to stand for a few minutes in a water bath heated to about 98.6°F. After a few minutes they are tested for starch content using Lugol's solution.

Results

The results are given below:

Test tube	*Observation*	*Deduction*
Normal pH	Almost no color	Digestion takes place
Hydrochloric acid	Dark blue	No digestion
Sodium hydroxide	Dark blue	No digestion

Discussion

It would seem that when ptyalin comes into contact with either an acidic or an alkaline media, its digestive activity ceases. However, the pH values of these conditions were not determined and perhaps under less acidic or alkaline conditions digestion would be observed. An experiment may be designed to refine this investigation.

EFFECT OF TEMPERATURE ON STARCH DIGESTION

Introduction

Ptyalin is an enzyme contained in the saliva of most humans. Its function is the digestion of starch. Under what conditions does it perform its function best? What are the effects of temperature upon digestion of starches? It is believed that most enzymes have an optimum temperature for functioning, hence the same might also be true for ptyalin. If body temperature is optimal for starch–sugar conversion by pytalin, temperatures differing from the optimal then will show decreases in the rate of conversion.

Experiment

Four solutions were needed for this experiment. The solution was obtained by first washing out the mouth and then chewing some paraffin wax to stimulate secretion. The saliva was diluted with distilled water to make a 10% solution. The starch solution was made by adding 50 gms of starch to 200 ml of hot distilled water. The testing solutions were Benedict' s solution obtained from the medical store and Lugol's solution. To each of ten test tubes 10 ml of starch solution was added. In five of these test tubes the saliva solution was added giving us two groups–five test tubes with saliva and five test tubes without saliva.

From each group one test tube was immediately put on ice; in a similar manner two test tubes were kept at room temperature; two test tubes were placed in a water bath whose temperature was kept 58°C; the last two test tubes were placed in a bath of boiling water 10°C. At intervals of ten minutes two samples were taken from each test tube, one tested for the presence of starch and one tested for the presence of sugar.

Results

The results are given below:

A. Starch Test

Solution Type	Time in Minutes	Sample at 100°C	Sample at 58°C	Sample at 38°C	Sample at Room Temp.	Sample at 0°C
Enzyme	After 10	Dark Blue	Dark Blue	Light Blue	Light Blue	Dark Blue
"	" 20	"	"	"	"	"
"	" 30	"	"	Very Lt. Blue	"	"
"	" 40	"	"	" "	"	"
"	" 50	"	"	" Pale "	"	"
"	" 60	"	"	Almost Colorless	Lt. Violet	"
No Enzyme	" 10	"	"	Pale Blue	Dark Blue	"
"	" 20	"	"	"	"	"
"	" 30	"	"	"	"	"
"	" 40	"	"	"	"	"
"	" 50	"	"	"	"	"
"	" 60	"	"	"	"	"

B. Sugar Test

Solution Type	Time in Minutes	Sample at 100° C	Sample at 58° C	Sample at 38° C	Sample at Room Temp.	Sample at 0° C
Enzyme	After 10	Pale green	Greenish	Yellowish	Pale Green	Pale Blue
,,	,, 20	Greenish	,,	,, red	Greenish	,,
,,	,, 30	,,	,,	Red-brown	,,	,,
,,	,, 40	,,	Yellowish	,,	Yellow	,,
,,	,, 50	Yellowish	,,	,,	,,	,,
,,	,, 60	,,	,,	,,	,,	,,
No Enzyme	,, 10	Pale Green	Dark Blue	Pale Blue	Pale Blue	,,
,,	,, 20	Greenish	Pale Green	,,	,,	,,
,,	,, 30	,,	,,	Pale Green	,,	,,
,,	,, 40	,,	,,	,,	,,	,,
,,	,, 50	Yellowish	,,	,,	,,	,,
,,	,, 60	,,	,,	,,	,,	,,

Questions

1. What conclusions can we draw from the data?

2. Why does the starch solution containing no enzyme test positively for sugar?

3. Must we take equal amounts of Benedict's solution, starch, and saliva solution for all the above conditions?

4. What is the reason for your answer?

5. Have any variables been left uncontrolled?

6. When an enzyme is boiled what happens to it?

7. After raising the temperature of an enzyme and allowing it to cool, is it as effective as an unboiled sample of enzyme? How could you find this out? What would be your control?

8. In the experiment that you just did were there any control groups left out? What is the reason for your answer? How could this be controlled?

9. What is the effect of boiling starch solution only?

10. Give a detailed description and analysis of the experiment on digestion that you have just completed. What are your conclusions? What are your generalizations (if any)?

11. How could you test the hypothesis that if time is increased for digestion the amount of sugar will be increased? Give a detailed description of the design of such an experiment.

COTYLEDONS

Introduction

The young seedling first sprouts a cotyledon. Later on the cotyledon withers away. The cotyledon contains nutrients and other materials essential for the growth of the young plant. At what time will the green plant become independent of its cotyledon?

Experiment

Fourteen batches of twenty bean seeds were weighed out. The first batch of seeds was soaked overnight and planted the next morning. That evening the second batch was soaked and planted the following morning. This procedure was repeated until all the batches were planted. On the morning after the last batch was planted each batch was collected, cleaned of any soil that might have clung to the seeds, and weighed immediately. This figure was called the total "fresh weight." The batches were divided up into two groups. From one group the cotyledons were cut off and weighed. (Each batch was kept separate.) This figure was the cotyledon's fresh weight. The second group of each batch was placed out in the sun so that the water was removed. After they were dry, each batch was weighed to find the dry weight. The dry cotyledons were cut off and weighed. Average weight for each batch was recorded in the report.

Results

Batch	Average Fresh Total Weight.	Average Cotyledon Fresh Weight.	Average Dry Total Weight	Average Cotyledon Dry Weight
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				

Questions

Plot each of the following on a piece of graph paper as a function of batch age: Average Total Fresh Weight, Average Cotyledon Fresh Weight, Average Dry Total Weight, Average Cotyledon Dry Weight. Relative batch age will be given by the inverse of the batch number. Can you tell from the graph where the young plant became independent of its cotyledon and began to live on its own photosynthetic products?

EFFECT OF DIFFERENT WAVELENGTHS OF LIGHT ON PHOTOSYNTHESIS

Introduction

Photosynthesis occurs in sunlight. Sunlight or white light is composed of many different wavelengths of light.

If the absorption spectra of chlorophyll is an indication of the wavelengths of light which are necessary for photosynthesis, then red light and violet light will produce more starch in a leaf than other colors.

Experiment

Procedure: We took a number of leaves with approximately the same characteristics and from the same plant. A number of beakers were filled with various colored liquids including red green, blue, yellow, orange and violet being sure that all of the colored liquids were of the same brightness and that they are at equal levels in their beakers. One leaf was placed under each beaker so that no light will fall on the leaf except the light that passed through the colored liquid in the beaker. All the beakers were put with the leaves below them in approximately the same place in the sunlight. Another leaf was placed under a beaker with cloudy water in it so that the sunlight falling on this leaf through the beaker was judged to be of the same intensity as that falling on the other leaves. After all the leaves had been left in the sun for a day, each of them was tested for starch.

Questions

1. Where there any variables that were left uncontrolled?

2. What would you predict to be the effect on the results if the intensity variables were left uncontrolled?

3. How can we extract chlorophyll and demonstrate its absorption spectra?

4. Identify the dependent variable, independent variable and the control in this experiment.

5. Would you expect, using only one leaf for each experimental condition, that your data would be precise?

6. How could you check to see if there was any starch in the leaves before they were exposed to the experimental conditions? Is this important?

7. What would you expect the results would be if the experiment were conducted on leaves which were left on the living plant?

8. Could the above condition effect your results?

9. What experiment does this suggest?

HINTS FOR BIOLOGY INVESTIGATIONS

1. What foods contain fats? Crush food materials and drop some in the bottom of a test tube. Cover the food material with a few drops of carbon tetrachloride. Let the material stand for about ten minutes and then pour a few drops on a piece of white paper. After the carbon tetrachloride has evaporated, examine the paper. If the food contains fat, there should be a transparent grease spot on the paper. Remember, carbon tetrachloride vapors are dangerous to breathe.

2. What is the effect of carbon dioxide on plant growth? Will plants live in an atmosphere of pure carbon dioxide? In an atmosphere of no carbon dioxide?

3. What is the effect of oxygen on plant growth? Can a plant live in pure oxygen? In air lacking oxygen?

4. In which color of light do plants grow the best? Cover a few leaves with one color of cellophane, a few leaves with other colors and test for starch formation.

5. Which organisms in water seek light? Which avoid light? Cover 3/4ths of a narrow mouth jar with dark paper. Allow it to set for two days in moderate light. Examine the dark portion and light portion under the microscope.

6. Is bacteria found in the air? In the soil? In water? On animals? Or on yourself? - Check by growing bacteria cultures on slices of potatoes. Expose one section to the air for one hour and add or touch other slices to the other media. Cover. Examine after two days.

7. Which seeds grow the fastest? Line the inside of a glass or jar with several layers of newspaper. Place several different types of seeds between the glass and paper. With the glass half filled with water, observe the sprouting of the different seeds.

8. What is the rate of growth of roots and where is the growing region on the root? Mark off a young root with India Ink and keep moist. Observe every day.

9. How does a young leaf grow? Mark a square grid on the surface of a young leaf with India Ink. Observe the growth over a few days.

10. How long does it take mosquitoes to digest blood? You can see the red coloration of blood through the swollen abdomen of a well fed mosquito.

11. What is the walking order of the legs of various types of insects? How does the insect modify his walking pattern with removal of one or more legs?

12. How do ants follow the trail of other ants? Is the trail memorized by the ants or are they orientated by light? Do they smell the trail? Try destroying and making trails with formic acid.

13. What insects have the power of breaking off their body parts? Which ones can regenerate these parts? Does regeneration of legs occur just in the young insects or can adults do it too?

14. Do seeds digest starch? Crush bean seeds and then test for starch and sugar. Place other bean seeds on a wet blotter until they germinate. Test again for starch and sugar.

15. How does the blood clotting time of various animals compare with humans? To determine the clotting time, heat a piece of glass tubing. Pull the ends apart so you have a length of fine tubing. Sterilize the tip of your finger with spirit. Prick with a needle. Place the glass tubing over the drop of blood. The blood will rush up the tubing. Examine a small bit of the tubing every 15 seconds. When you observe fine threads being formed, this is the blood clotting time.

16. What is the average heart beat of students in your room? Does the average heart beat change with age? What effect do different amounts of activity have on the heart beat? What is the average heart beat of different animals?

17. Locate the valves in your veins. Pump your fist open and closed for several minutes in order to make the veins in your arm stand out. Start at your elbow and move your finger along the vein toward the wrist. You will force the blood out of the vein. The vein will be empty from your finger to the valve.

18. When other variables are constant, how does digestion of various substances progress through time?

19. What are the effects of increased temperature on the respiration of a cockroach?

20. What is the absorption spectra of chlorophyll?

21. What is muscular fatigue? How can we demonstrate it?

22. What are the effects of increased stimulating voltage on the reactions of a frog's leg muscle?

23. What are the effects of increasing stimulus duration on the reactions of a frog's leg muscle?

24. How will recovery times be effected under conditions of repeated fatigue in a frog's leg muscle?

25. What are the effects of adrenalin and acetylcholine on the beating rate of a frog's heart?

26. What are the pigments in a leaf? What are the effects of soil condition upon the presence of these pigments?

27. What is a reflex? Under what conditions can a reflex be observed in a frog? How do these conditions lead us to an understanding of the physiology of a reflex "arc"?

28. What are the sizes of the pores in a plastic membrane?

29. If a plant is deprived of the food-making capacity of many of its leaves yet still retains those leaves, can it remain healthy? What will happen to those leaves which are deprived of sunlight?

30. Does osmotic pressure increase as the temperature of a given solution rises?

31. How does the change in osmotic pressure due to temperature compare to the change in osmotic pressure due to differences in concentration of the solution?

32. If the temperature of an enzyme increases, does its rate of activity also increase?

33. What are the effects of variations of light intensity upon transpiration?

34. What is the effect of environmental temperature on the metabolism of man?

35. What is the effect of yeast on fermentation.

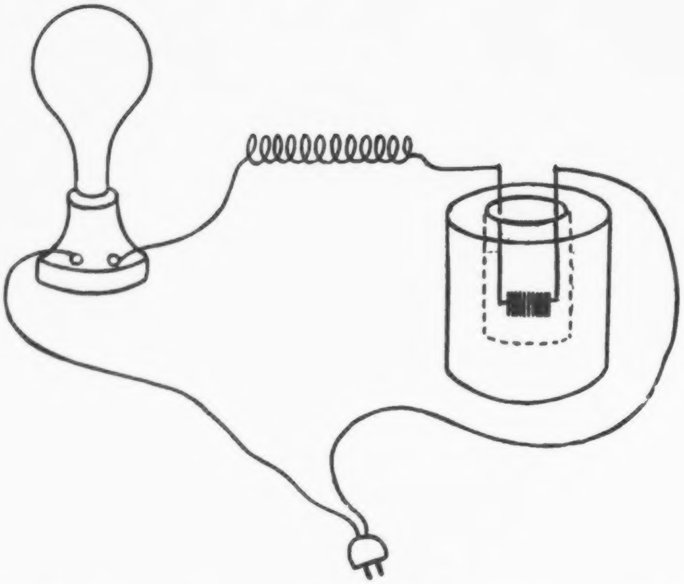
Physics

PRODUCTION OF HEAT IN ELECTRICAL RESISTANCES

Introduction

It is often observed that an electric conductor becomes hot when current is passing through it. It is also known that electric stoves have conductors of high electrical resistance and that heat seems to be constantly produced as long as the current is left on. The heat produced by a current might be a function of the resistance of the conductor and the duration, in time, of the current.

APPARATUS FOR MEASURING HEAT PRODUCED BY ELECTRICAL RESISTANCES



Experiment

Apparatus : The apparatus consisted of one calorimeter, one 50 watt Bajaj light bulb, and 40 gauge nichrome wire.

Procedure: The bulb was connected by copper wire in series with two lengths of nichrome wire, one 3′ length insulated, one 1′ length bare. The bare length of nichrome wire was placed in a calorimeter with 100 ml of ethylalcohol (specific heat = .65). The alcohol was stirred until it was determined that the temperature had approached an equilibrium value. The current was then turned on and the alcohol constantly but gently stirred Temperature readings were taken at intervals of two minutes up to a total of 10 minutes. The same procedure was followed with lengths of 2′, 3′ and 4′ of bare nichrome wire inside the calorimeter. With the 2′ length of bare nichrome wire inside the calorimeter, the 3′ insulated length of nichrome wire outside the calorimeter was replaced by a 2′ insulated nichrome wire, thereby keeping the total electrical resistance of the apparatus constant (therefore the current strength in amperes was constant). Correspondingly, when the 9″ bare wire was in the calorimeter, only 1′ insulated wire was used outside it, and no insulated wire was used when the 5′ length was inside.

Results

The observations are given below :

Table 1

Temperature of Alcohol

Wire Length	0 minutes	2 minutes	4 minutes	6 minutes	8 minutes	10 minutes
1'	24°	25.5°	26.5°	28°	30°	32°
2'	26°	29°	31.5°	34.5°	38°	40°
3'	25°	29°	33°	38°	42.5°	47°
4'	24°	29°	35°	41.5°	48°	54°

Table 2

Change of Temperature Table

Wire Length	2 minutes	5 minutes	6 minutes	8 minutes	10 minute
1'	1.5°	2.5°	4°	6°	8°
2'	3°	5.5°	8.5°	12°	14°
3'	4°	8°	13°	17.5°	22°
4'	5°	11°	17.5°	24°	30°

Table 3

Change of Temperature Table for 40 Guage German Silver Wire

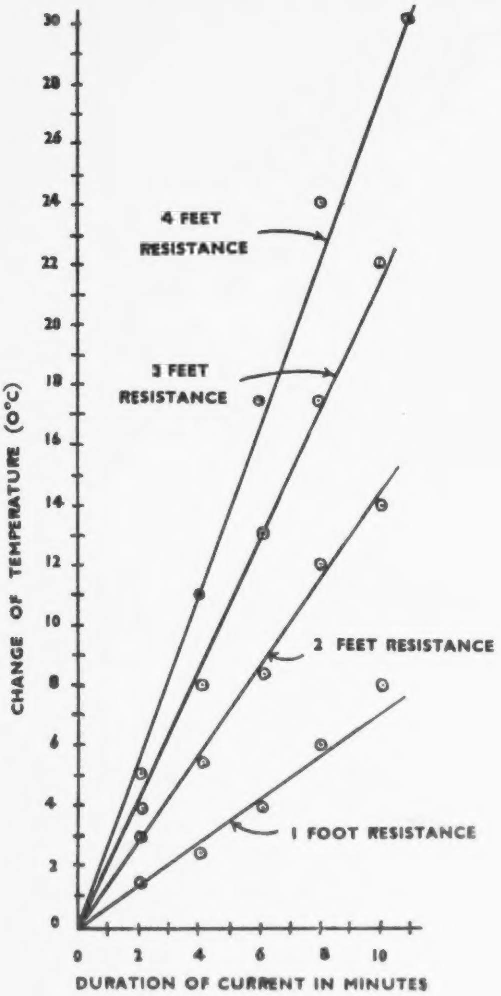
Time Resistance	2 minutes	4 minutes	8 minutes
1'	.5°	1°	2°
3'	1°	2°	5°

Discussion

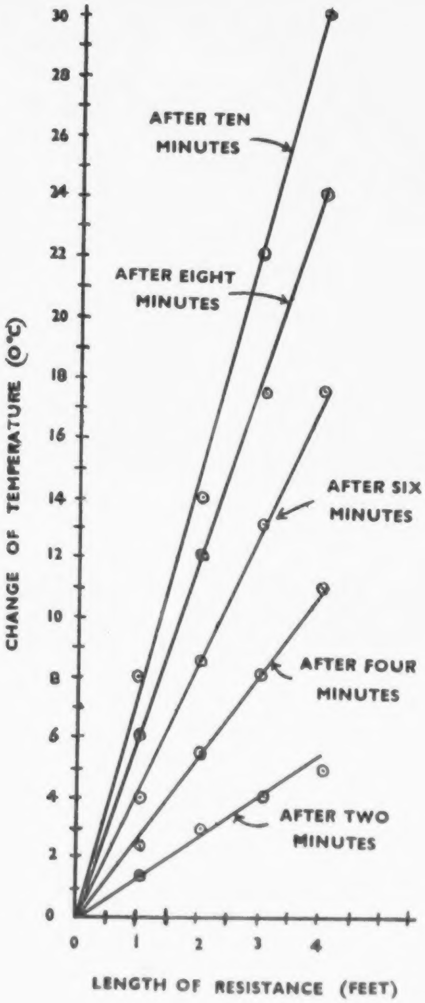
The data recorded in Table I is simply the observations for each reading. Table II gives the actual change in temperature for each reading. If we plot the temperature change as a function of time, as in Graph I, we find that there is a constant relationship between time and temperature for each resistor. That is, C = kT, where C is the change in temperature, T is time and k is a constant. Since the temperature change in the alcohol is directly proportional to the heat gained by the alcohol (which equals the heat given by the resistor), then the heat given by the resistor is directly proportional to the time for which there is a current, given constant voltage, resistance, and amperage. That is, if all other factors are constant, H = kT (where H is the heat produced, T is time, and k is a constant).

In plotting temperature change as a function of resistance (Graph II), we find a constant relationship between temperature change and resistance for each duration of time (since the resisance of the wire is proportional to its length). This can be false only if the the change in temperature was actually

I. CHANGE OF TEMPERATURE VERSUS TIME



II CHANGE OF TEMPERATURE VERSUS RESISTANCE



related to the surface area exposed rather then the resistance of the wire. Therefore, a control was used: German silver wire (number 40 gauge), which has 2/7 the resistance of the nichrome wire but the same surface area, was tested for resistances of one foot and three feet. and for times of two minutes, four minutes, and eight minutes. In all cases the temperature changes were found to be two sevenths of the temperature changes for the corresponding times and resistance lengths using nichrome wire (Table III). Therefore the temperature change was not a function of surface area exposed, but rather in direct proportion to the amount of resistance, as shown in graph II. Since the temperature change is directly proportional to the heat gained by the alcohol (which equals the heat lost by the wire), then the heat given by the wire is directly proportional to the resistance of the wire ($H = kR$; H is heat, R is resistance, k is a constant).

It is worthwhile to mention here that amperage was kept constant by removing resistance from the circuit outside the calorimeter equal to the resistence added inside the calorimeter.

Sources of error include the heat lost in the calorimeter, possible inaccuracies in the thermometer and human judgment in reading the thermometer.

The experiment was conducted under conditions of constant voltage and amperage; it may be that one or both of these factors might also influence the heat given by a conductor.

Summary

An experiment was conducted to test whether the heat produced by a conductor is a function of the resistance of the conductor and the duration in time for the current. Using nichrome wire, it was found that the heat produced was directly proportional to each of these factors. In establishing the validity of the relationship between resistance and heat produced, it was also shown that the heat produced was not a function of the exposed surface area of the conductor.

INTENSITY OF REFLECTED LIGHT

Introduction

It is a well known phenomenon of optics that if a light beam is reflected by a transparent surface, the reflected beam will not be as intense as the incident beam. This is because some light is refracted by the surface medium. It has also been observed that a viewer can see little or no light reflected from a surface when the incident light it normal to the surface, yet can see relatively more light reflected if the light strikes the surface at an oblique angle.

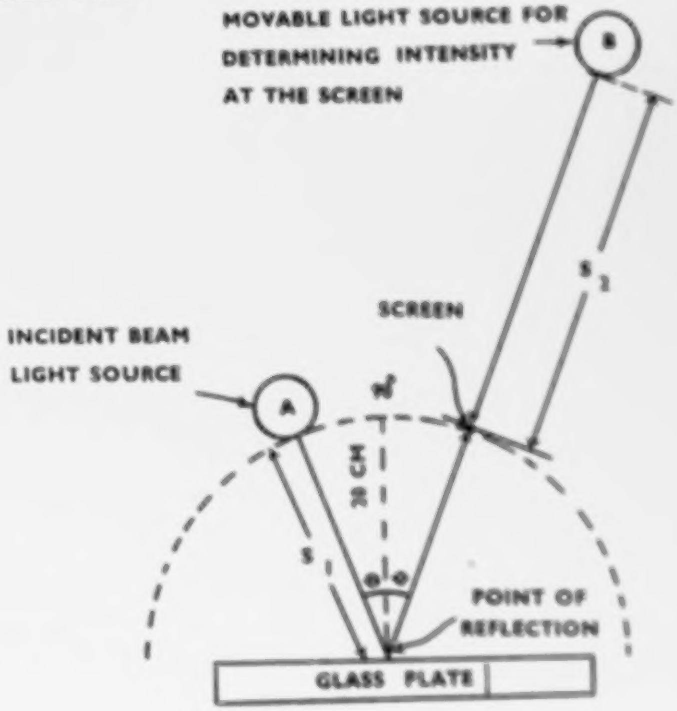
Perhaps the amount of light reflected depends upon the angle of incidence of the light beam. Specifically, if the angle of incidence of a light beam reflected from a smooth glass surface is changed, then the amount of light reflected by that surface will also be changed.

Experiment

Apparatus: The apparatus for measuring relative light intensity was set up as following: Two new Phillips 100 watt light bulbs were placed in closed containers coated on the inside with dead black paint. A hole of 1 mm diameter was drilled in each container, providing a beam of light from each. A drop of cooking oil was applied to a sheet of white paper, which was then held in an upright position. Light sources were focused on each side of the paper screen. When the grease spot was judged to disappear (after moving the light sources to appropriate distances) the screen was receiving equalillumination from both sources. If the distance of light source A from the screen is 1 and the distance of light source B from the screen is S_2, and if the grease spot is seen to disappear, then the relative intensity of light source B to light source A equals $\frac{(S_2)^2}{(S_1)^2}$.

DEVICE FOR MEASURING REFLECTED LIGHT

FIGURE No. 1



The apparatus consisted of the two light sources, the grease spot screen, and one glass plate with a smooth surface.

Procedure: The experiment was conducted in a dark room. One light source was put at a distance of 20 cm from the point of reflection and at an angle of 10 degrees to the normal at that point. The paper screen was then put also at a distance of 20 cm from the point of reflection in a position intercepting the reflected beam. On the side of the screen opposite to that of the mirror was placed the second light source, which was adjusted to a distance making the grease spot disappear. This distance (from the screen to the second light source) was recorded. This procedure was followed three times for each of the following angles (to the normal): 10°, 20°, 30°, 40°, 50°, 60°, 70°, and 80°.

Results

The results are given below :

Angle	Distance of incident Source S_1	Distance from Screen to 2nd Light				$\frac{(S_2)^2}{(S_1)^2}$	$4\frac{(S_2)^2}{(S_1)^2}$
		1st Reading	2nd Reading	3rd Reading	Average		
10°	20 cm	1.9 cm	2.1 cm	2.1 cm	2.0 cm	1.00%	4.00%
20°	20	2.2	2.1	2.3	2.2	1.20%	4.80%
30°	20	2.3	2.2	2.3	2.3	1.32%	5.28%
40°	20	2.4	2.2	2.1	2.2	1.20%	4.80%
50°	20	2.7	2.5	2.7	2.6	1.69%	6.76%
60°	20	3.4	3.1	3.2	3.2	2.56%	10.24%
70°	20	4.3	4.4	4.5	4.4	4.84%	19.36%
80°	20	6.4	6.6	6.4	6 5	10.56%	42.24%

Discussion

Since the intensity of light on a surface is inversely proportional to the square of the distance between the light source, and the surface, then when two light source. A & B, (at distances S_1 & S_2 respectively), equally illuminate the surface, the relation of the intensity of source B to the intensity of source A is given by $\frac{(S_2)^2}{(S_1)^2}$

In the data column the relative intensity of the reflected light, at its point of interception by the screen, to the incident light at the point of incidence is $\frac{(S_2)^2}{(S_1)^2}$. Since the light travelling from the incident beam source travels twice as far to reach the screen as to reach the reflecting surface, the intensity of light reflected, at the point of reflection is 4 times the intensity of the reflected beam at the screen.

Thus the percentage of the incident beam that is reflected by the glass at the point of reflection is given by $4\frac{(S_2)^2}{(S_1)^2}$.

On plotting the percentage of relected light as a function of the angle of incidence, it was found that for small angles of incidence, (50 degrees and above) the percentage of reflected light increased more rapidly with given increases of incidence angles.

Sources of error included the possiblity that the two light sources might not have been equal intensity. There was also the factor of human judgement involved in determining at exactly what point the grease spot disappeared. Measurement of distances were made to the neareast millimeter, thereby allowing upto .5 mm error in recording distances.

After examining the data, the problem arises that the relationship between percentage of reflected light and angle of incidence might be a function of a third factor, such as the index of refraction or the density of the reflecting surface material.

An experiment was conducted to test the hypothesis that the percentage of a light beam reflected from a glass surface is a function of the angle of incidence of the light. The percentage of reflection was found to increase as the angle of incidence (to the normal) increased The rate of increase of the percentage of reflected light was found to be lower for angles under 50 degrees and higher for angles above 50 degrees.

THE RATE OF FLOW OF A LIQUID

Introduction

It has often been noticed that different liquids seem to flow at different rates. Pitch or tar seem to flow more slowly than water, and it is known that glass in its normal state is a liquid with a very slow rate of flow; after 10 or 20 years a glass pane in a window can be observed to be thicker at the bottom than at the top.

There may be a relationship between the rate of flow of a liquid and its density.

Experiment

Apparatus: The apparatus consisted of a small mouth bottle with a hole on one side cut near its bottom. Into this hole was fixed a glass tube (length 50 cm, diameter 0.2 cm) by means of a cork. Potential leaks were sealed. The top of the bottle was fitted with a one–hole stopper which held a glass tube, the lower end of which was at a level 2 cm above the level of the horizontal tube If the vertical tube is not sealed and the bottle is full of a liquid, then it (the liquid) is known to have a constant rate of flow through the hole in side of the bottle.

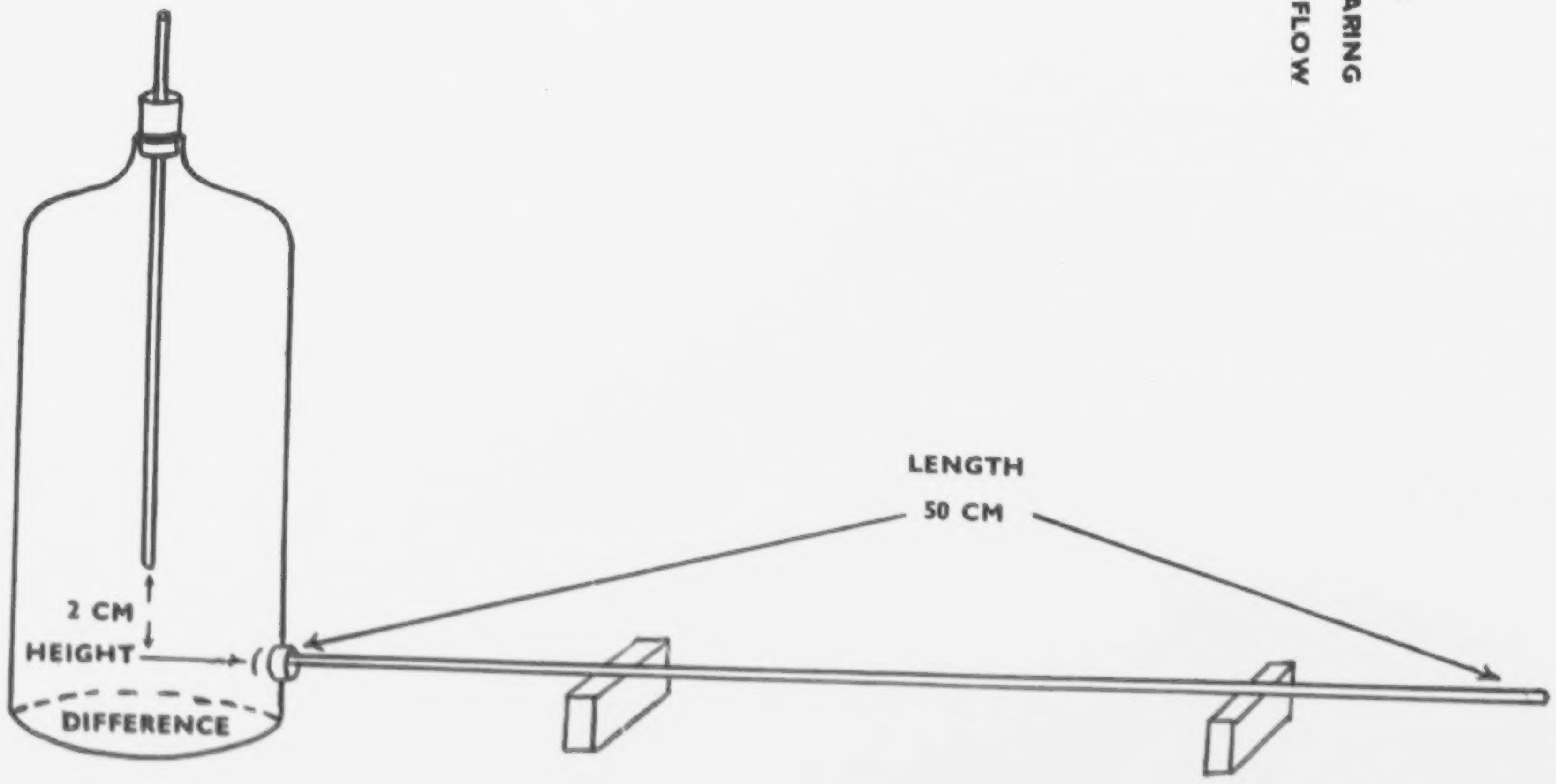
Procedure: Five liquids were taken–alcohol, turpentine, sucrose solution, water and glycerine. The alcohol was then poured into the bottle, completely filling it. The cork and glass tube (which was sealed to prevent the entrance of any liquid) was then placed in the bottle top. The vertical tube was then unsealed and the time taken for the alcohol to reach the end of the 50 cm tube was recorded. This procedure was followed for each lquid.

Results

The results are given below :

Liquid	Density	Time Taken to Flow 50 cm	Rate of Flow
Alcohol	0.78	10 seconds	4.9 cm/sec
Turpentine	0.87	13 "	3.8 "
Sucrose solution (30%)	1.09	24 "	2.1 "
Water	1.00	12 "	4.2 "
Glycerine (30%)	1.07	19 "	2.6 "

APPARATUS FOR COMPARING RATES OF FLOW


LENGTH
50 CM
2 CM
HEIGHT
DIFFERENCE

Questions

1. What is the ratio of the liquid with highest density to that with the lowest density? What is the ratio of the fastest rate of flow to the slowest?

2. Draw a graph of the results. Does it indicate any relationship between density and rate of flow?

3. Why is the flow of liquid out of the bottle constant?

4. If you were to raise the vertical tube would the liquid flow faster or slower?

5. If the horizontal tube had a larger diameter, would it affect the rate of flow of the liquid? Why?

6. What would happen if the temperature were different?

FALLING VELOCITY IN A LIQUID

Introduction

When a solid is placed in a liquid it moves either up or down, due to the difference between upward pressure of the liquid and the downward force of the weight of the object and the downward pressure of the liquid. For a body of a given size or shape, there will be a net difference between the downward liquid pressure and the upward liquid pressure on it. Since liquid pressure is proportional to liquid density, it would seem that the net difference between the upward and downward pressure of a liquid on an object will be greater in more dense liquids. If this is true, then the liquid density will affect the net force on an object moving through that liquid. The acceleration of an object falling through a liquid is related to the density of the liquid.

Experiment

Apparatus: The appratus consisted of a tubelight, 100 cm long, opened at one end and cleaned. Also a small irregular shaped stone (volume 1.9 cc, density 2.3 gm/cc).

Procedure: Water was poured into the tube up to a height of 100 cm. At the top of the water column the stone was released and the time it took to reach the bottom was recorded. This procedure was repeated with liquids of the following specific gravities: 0.78, 1.15, 1.5, 1.9, 2.0.

Results

The results are given below :

Density of the Liquid	Time Taken to Fall 100 cm	Acceleration $= \frac{2h}{t^2}$
0.78	0.5 seconds	800.0 cm/ sec^2
1.00	0.6 "	555.6 cm/ sec^2
1.15	0.8 "	312.5 cm/ sec^2
1.5	1.0 "	200.0 cm/ sec^2
1.9	1.2 "	138.9 cm/ sec^2
2.0	2.0 "	102.04 cm/ sec^2
		where h = 100 cm

Questions

1. Plot a graph of density versus acceleration. Is there an evident relationship ? Is there a trend ?

2. The pressure in any given liquid is larger at greater depths. Will this in any way effect the acceleration of the falling stone ?

LIQUID PRESSURE

Introduction

In liquids, pressure varies with depth. Liquids with different densities whose pressure is measured at the same depth may show differences in pressure. Will the more dense liquids exert greater pressure ?

Experiment

The pressure of kerosene was found at the depths of 1", 2", 3", 5", and 10" below the surface with the help of a U-Tube Manometer. This procedure was repeated again with kerosene. Water, turpentine, petrol, sweet oil, and milk were also tested twice at each level.

Questions

1. Why should each test be run several times ?

2. Do the more dense liquids exert greater pressure ?

3. Do the pressures exerted by a liquid increase directly as the depth increases? Are the rates of increase or decrease the same for all liquids ?

4. Does the difference in pressure exerted by two different liquids vary equally as the depth increases ?

5. What possible errors occured? How can they be corrected ?

STRENGTH OF ELECTROMAGNETS

Introduction

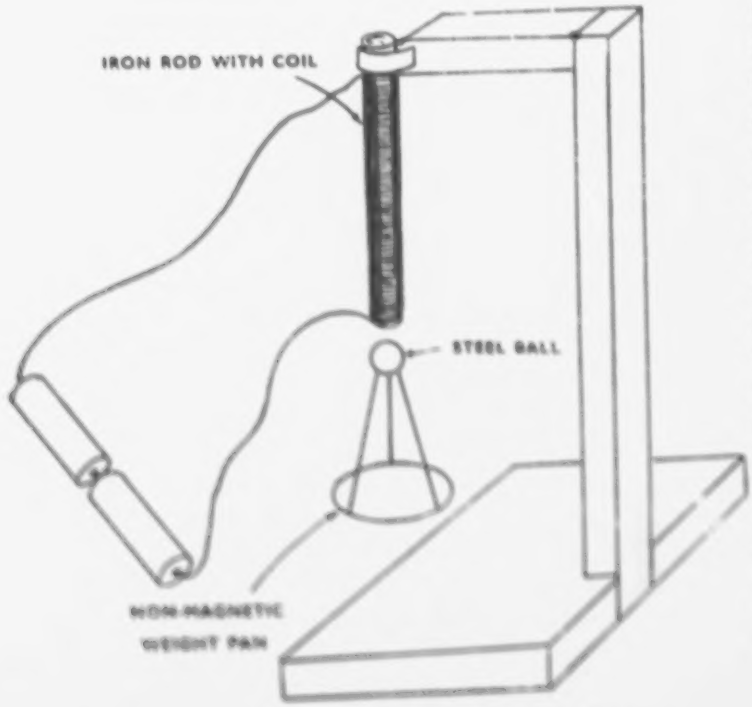
We know that the magnetic field strength of a coil in a tangent galvanometer varies directly as the length and number of turns of wire in the coil and inversely as the square of the radius of the coil. However, strength of the magnetic field seems to vary with the gauge of the wire used in the coil. What is the relationship between the gauges of the wire and the strength of the magnetic field created in a coil of fixed dimensions and a constant voltage ?

We know that the gauge of a wire is related to the diameter and therefore its cross-sectional area. We also know that this cross-sectional area determines the resistance of a conductor. Since (1) cross-sectional area increases as the gauge decreases, and (2) resistance decreases as the cross-sectional aree increases, then the conductor's resistanca should decrease as the gauge decreases.

With the decrease of resistance there should be an increase of current strength, given a constant voltage. An increase of current should bring an increase of strength in the electromagnet. Therefore, a decrease in the gauge of the wire conductor should bring an increase of strength of the electromagnet. Assuming that the maximum amount of mass supported at the bottom of an electromagnet is a measure of its magnetic strength, our hypothesis is that if there is a decrease in the gauge of the coil wire then there will be an increase in the maximum mass that the electromagnet will support.

DEVICE FOR MEASURING ELECTROMAGNETIC FORCE

FIGURE No. 1



Experiment

Apparatus: The apparatus consisted of a soft iron rod, supported vertically, 1 cm in diameter and 5" in length, about which was alternately wound 25 turns, 50 turns, 75 turns, and 100 turns each of the following gauges of copper wire (enamelled): gauge numbers 18, 22, 26, and 30. Each gauge wire was cut into lengths of 80 cm (25 turns), 160 cm (50 turns), 240 cm (75 turns) and 320 cm (100 turns) The apparatus also included a steel ball of 1 cm diameter and 3.95 gm mass which supported, by thread, a non-magnetic (plastic) weight pan of 1.1 gm. The source of direct current electricity consisted of two new torch-light cells giving about 3 volts electromotive force.

Procedure: The 80 cm length of gauge 30 wire was wound about the rod in exactly 25 turns. The coil was connected to the cells and the steel ball with the weight pan was placed against the bottom of the iron rod and allowed to be supported by the magnetic force. Gradually and carefully small amounts of mass (non-magnetic) were added to the weight pan until the assembly dropped. The total mass of the assembly was measured and recorded This was done three times. The procedure was then conducted three times with each coil wound with the prescribed number of turns, giving a total of 48 separate readings.

Questions

1. Why must the weights and weighing pan be non-magnetic ? What type of results would you have received if you did use magnetic weights ?

2. Did the same gauge wire produce the best electromagnet for each of the lengths.

3. Were the rates at which magnetic flux increased due to different gauge wires equal to each other ? Were they similar ?

4. With a decrease in resistance is there an increase of current (or magnetic force) ?

5. Could you predict from your data what gauge wire would be most effective ?

6. How does the strength of an electromagnet change as the temperature of the core varies ?

HINTS FOR PHYSICS INVESTIGATIONS

1. A photomenter, an instument used to measure the intensity of light, can be improvised by placing a piece of paper with a small grease spot on it between two light sources. If both sources are moved perpendicular to that screen until the spot disappears, the intensity of one source can be determined if the intensity of the other source is known by the formula;

$$\frac{I_1}{d_1^2} = \frac{I_2}{d_2^2}$$

Using the photometer and two white candles (whose intensity is usually 2 candlepower), and double convex lens, can you find out some relationship between focal length of the lens and intensity of light ? At what distance from the candle should the lens be placed in order to guarantee maximum intensity ?

What is the relationship between distance and intensity for a double convex lens, plano-convex, double concave, plano-concave, concave-convex ?

What is the light intensity of the moon compared to a candle or known source ? How does the diameter of the lens affect the amount of light admitted ?

2. If we use a photometer as described above, we can measure the intensity of a light source. If we assume that the intensity of an electrical light source varies directly with amount of current, we can also find the amount of current that is passing through the light source. What, then, is the relation of the distance between electrodes in a salt rheostat and the amount of current that passes ?

3. The specific heat of a substance can be measured by measuring the change in temperature of a known mass of that substance and an equal mass of water, given an equal source of heat for both and comparing them in the ratio of the change in temperature of the substance to change of temperature in water. The specific heat will then be given by :

$$\frac{\text{Rise in temperature of } H_2O}{\text{Rise in temperature of substance}}.$$

The specific heat of a sodium carbonate solution varies with the molarity of that solution. Is this a direct relation ? Does the temperature range in which the heating occurs have any effect on the specific heat ? Is there any relationship between specific heat of metals and their conductivity ?

4. All liquids have surface tension. That is, the molecules on the surface of a liquid have more attraction for one another than do the molecules below the surface, and therefore form something like a protective wall which does not allow anything to pass through that surface. A good example of this wall is the fact that we can float a razor blade on the surface of water; but, if we put it below the surface, it will sink. Another example is the beads of water that will form on a table when water is spilt. A simple device can be made to show surface tension and also to measure it. If we consider that the surface tension of water is 73.05 dynes/cm at 18°C, then, using very small masses (such as equal sections of thin paper), find the maximum amount of weight that the apparatus resting on the water's surface can carry. Can we relate this weight to maximum masses supported by liquids of other densities ? What is the surface tension of various liquids ? Does surface tension vary with temperature? If we mix two liquids whose surface tensions we know, is there a relationship between surface tension of the mixture and the surface tensions of the two component liquids ?

5. How does the tensile strength of a rubber band vary with its temperature ? A simple piece of apparatus to answer this question can be made out of a broken test tube, a one-holed rubber stopper and a piece of glass tubing. The one-holed rubber stopper with the glass tubing in it, is inserted into the unbroken end of the test tube. One end of the rubber band is pushed through the glass tubing and a small weight is attached. The other end of the rubber band is fixed in place in the tubing. The temperature of the water inside the test tube can be varied and the distance the rubber band extends under various temperature conditions can be found.

6. Will magnets attract things through paper? Through tin ? What materials will magnetism pass through ? Metals? What metals will magnets attract ?

7. What materials are easy to magnetize ? What materials are difficult to magnetize ? How long will these materials remain magnetized ?

8. If an electric current can be used to make a magnet, can a magnet be used to make an electric current? Attach a coil of wire to a galvanoscope. Move a magnet in and out of the coil of the wire. How does the strength of the magnet or the number of turns of the coil effect the amount of current? What kind of current is generated by moving a magnet back and forth through a coil?

9. What effect does the rate of moving the magnet back and forth through the coil have on the amount of current produced?

10. Does paper contain electricity? Rub a sheet of newspaper with a ruler while holding the sheet of newspaper against a smooth surface. How do you know electricity affects the paper? Can you see the sparks?

11. What causes static electricity? Try rubbing wool, silk, nylon, cotton and rubber. Do these materials become charged? Try other experiments with these materials, such as heating, cooling, hitting, etc.

12. Do all magnets attract things with the same amount of force? If you attach the centre of a magnet to a piece of string and hang it, you can have a simple device for measuring the force of a magnet. The amount the magnet turns when another magnet is brought near it can be read off in degrees. You can compare strengths of different magnets or measure the strengths with which a magnet attracts various substances.

13 Do both ends of a magnet attract objects, with the same force? Do both north poles and both south poles push away or repel with equal force?

14. Does the strength of the magnetic force increase or decrease as you move the magnet away from a piece of iron or steel? What is the relationship between distance of separation and magnetic force?

15. What effect does heat have on a magnet? Magnetize a nail and then heat it on a spirit lamp. Test with the apparatus described in 12. What effect does hitting a magnet have on its strength?

16. What materials can be charged with static electricity? What materials cannot be charged? Will materials that can be charged also can be affected by a magnet?

17. What effect does the strength of the electric current have on the amount of metal deposited by electrolysis? What effect does the length of time the current flows have on the amount of metal deposited during electrolysis?

18. What effect does temperature have on the conductivity of various metals? Connect a battery to a galvanometer and to a strip of bare wire. Heat the wire. Is the effect the same for copper, iron and nichrome wire?

19. How does the number of turns of wire around the iron core in the primary (the wire with the current flowing through) affect the voltage of the outside coil of wire in which the current is induced (secondary)?

20. Can you make a light bulb that won't burn out? Compare your bulb with standard commercial light bulbs. Record the life and brightness of both.

21. What is the difference between lights wired in series and those wired in parallel ? Measure the voltage and amperage at various points in the circuit.

22. You can use the heating effect of an electric current to measure electricity. Send and electric current through a cold iron wire. Note the change in the wire as it gets hotter. Does it corespond directly with the current ? Are the rates of different metal wires the same ?

23. What effect does the length, material, cross-sectional area, and temperature have on the resistance of a wire ? Set up an experiment using different types and kinds of wire. Keep the voltage constant; measure the amperes or amount of current. From the voltage and amperage you can determine the resistance.

24. Will a magnet have any effect on an electric current flowing through a wire ? Stretch a size No. 24 wire about 6 feet long between two insulated supports. Connect the wire to an alternating current supply. Use a rheostat to vary the current. Bring one end of a strong bar magnet near the wire while the current is flowing.

25. How do different kinds of soil affect the amount of run-off water that results from a thunderstorm or cloud burst ? This can be done in the classroom by placing different samples of soil (about 15 kgs) on a board, slant the board and pour water on it. Measure the amount of run-off water and washed away soil.

26. How much does a human hair contract and expand when exposed to changing humidity ? Tie a weight to one end of a hair and attach the other end to a lid of a dry jar, then add a little moisture to increase the humidity. Record the length of the hair.

27. Does oily or dirty hair affect the contraction rate of hair due to humidity? How does the human hair compare with hair from other animals in terms of contracting and expanding during humidity ?

28 At what rates do other materials expand and contract with changing humidity and temperature ?

29 Is there a relationship between the specific gravity of a liquid and the size of a drop of it ?

30 What are the sizes of the pores in a plastic membrane ? Which solute particles will diffuse through the membrane ?

—:o:—

Science Fairs

The greatest value of the science fair is the recognition and encouragement that it gives to the student participants. The school science fair is important because it can include all students who have done projects; it can be arranged as an exhibition for the school day. The district level fair has the value of providing a wide range of exchange of ideas for teachers and students. All science fairs are forums where ideas and techniques presented by the participants can be picked up and developed by others.

The following chapter gives some suggestions intended to help you organize and carry through a science fair or exhibition which will be beneficial for participants and visitors alike.

ORGANIZING SCIENCE FAIRS

Organizing committees

The presence of your science club can make organizing the school science fair simpler since through the club responsibility can be assigned to a number of people rather than just a few. You can delegate authority to various committees of science club members, such as the following:

1. A Central Committee, with you as a consultant, could decide on the date, location, participants, financing, and rules of the fair. It could also oversee the activities of the other committees making sure that they complete their assignments. They could make decisions on the following questions:

a. Who can enter the fair? You could allow any interested student to enter, even if he is not a science club member.

b. Shall there be an entry fee? How much? Although it is not likely you would need any money for a school science fair, a taluk wide fair might ask for 10 or 20 n.p. from each participant to help pay for publicity, prizes, and other expenses; the science club treasuries could pay for the remaining expenses.

c. When should applications be submitted? It would be wise if all final applications were submitted a week to ten days in advance of the date of the fair so that other committees would have time to make proper arrangements and preparations.

d. What type of exhibits will be accepted? It would be good to establish several categories of projects so that projects of the same type might be judged as a group against one another.

The following list is an example of such categories:

1. Charts
2. Collections
3. Models—static
4. Models—working
5. Experiments
6. Investigations

2. An Exhibits and Resources Committee would receive applications and prepare adequate space and tables for each exhibit. It should organise the exhibits into subject areas and assign each exhibitor a specific location for his project.

3. A Publicity and Judging Committee would notify all students of the date, place, categories, and other specifics of the fair. If it is a school fair, this committee could notify teachers from nearby schools. It should provide each student with an application blank or at least inform potential participants what to include on their application forms (name, class, type of exhibit, subject area of exhibit, name of exhibit). It should also let the participants know the standards for judging, and it could invite individuals to act as judges.

List of entrants

Several days before the established date of the science fair, a tentative list of entrants should be compiled. This list could include the name, class, teacher, title and category of the project of each possible entrant. The tentative list is merely a rough estimate and will be more than the actual number of entrants, because a certain number of students may not complete their intended projects. The tentative list is useful for the following purposes:

1. To determine how much space will be needed.

2. To determine how many awards will be needed.

3. To know who will need formal entry applications.

4. To present information about project specifications, dates, time and places to each entrant.

5. To present information about the judging criteria to each tentative entrant.

Time schedule

Time will be an extremely important feature in planning the science fair. A schedule should be made so that events do not occur in a haphazard fashion. When planning the time schedule for the science fair, remember that enough time must be provided for the following:

1. To set up tables or other furniture before the exhibits arrive.

2. For students to set up and test out their projects before judging.

3. To allow judges to complete judging without rushing.

4. To permit tabulation of judges' scores.

5. To meet and solve emergencies.

6. For the public to view the projects.

7. For students to dismantle the projects.

8. To clean up the display area.

Arranging the exhibition

Several important points should be kept in mind when arranging the actual site of the science fair:

1. Be sure adequate exhibit space is available.

2. As far as possible, each entrant should be given the same amount of space in which to set up his project.

3. Projects requiring such things as water or electricity should be allotted a space where these things will be readily available.

4. Projects of the same type should be placed together because:

a. They can be viewed with more understanding by the public.

b. Students would find themselves in company with other students of like interests.

c. Judges would be able to evaluate the projects more effectively.

5. Projects should be arranged so that one does not distract from another if possible.

6. The exhibits should be kept close to eye level. The easiest way to do this is to display them on tables or hang them on walls or blackboards.

7. As far as possible, uniform furniture should be used to display the exhibits.

Safety

In order to ensure the safety of projects, exhibitors, and public the following rules should be observed:

1. Electrical safety must be observed. No exposed switches, wires, or metal parts should be permitted. All wiring and connections should conform to reliable safety standards.

2. Any project involving high temperatures should be adequately insulated from flammable surroundings by asbestos board or other suitable insulation.

3. The exhibitor or an alternate should always be with the display.

4. Care of living animals and plants should be taken by the exhibitor himself.

5. No project should be permitted which may even remotely constitute a hazard to the public.

PREPARING FAIR EXHIBITS

Developing projects for the fair

Preparing projects for a science fair is a matter of thorough planning. In Chapter III we mentioned the possibility that investigative projects might take 7 to 12 weeks to complete. Other categories of projects might be simpler and require less time but they should also be planned to ensure quality. Planning should not be difficult since both projects and fair will be planned within the science club.

If your students are informed well in advance of the date and requirements of the science fair, you will have plenty of time to consult with them, help them to plan and keep them to schedules. With sufficient time the student will be able to reserarch the topic as thoroughly as he can, design and do his experiments and arrange an exhibit for his project.

Displaying the projects.

There are a few hints which you may give to the student to enable him to present an effective display.

1. An upright three-sided display board may be constructed which will contain the relevant facts of the project. Construction should be durable, and therefore materials which are stiff and which stand solidly–such as heavy cardboard, masonite, or ply-wood–should be used. If cardboard is used it will usually require reinforcement and back support so that it will stand solidly without curling.

2. If the display boards are joined, they should be securely hinged. Metal hinges can be used with heavy materials. Where cardboard is used, satisfactory hinges can be made with an adhesive tape.

3. The design should be started by making several rough sketches. Evaluate the arrangement of materials, lettering, and detailed enlargement. This should then constitute the proposed plan for the actual display.

4. Be sure to make the design eye-catching and attractive. Remember that each project will compete with many others for the attention of the judges and visitors. It should be designed so that it arrests the viewer's attention. However, gaudy, splashy, or bizarre designs should be avoided.

5. Make the display simple. Use an easy-to-follow design which can "shout out" its message in five to ten seconds. Remember that most viewers will spend only a minute or two with each project so be sure that they will have an opportunity to understand and appreciate the exhibitors efforts. Be sure to avoid the use of unnecessary decorations or "scattershot" arrangements. These tend to confuse instead of clarify.

6. The lettering should be large and simple. The titles should be short and descriptive and the narrative should be as brief as possible and to the point. It is best to use pictures, drawings, and diagrams whenever possible. These are better than detailed explanations. If the written discourse is long, it should be placed in a folder like a scientific paper, rather than attempting to place all of it on the display.

7. Select colors tastefully. A single pastel shade for background coloring is better than white, which tends to appear "vacant." Dark tones should be used to accent the areas which are to be emphasized. Certain color combinations are more appropriate for some types of projects than others. For example, greens and yellows suggest the natural sciences, reds and blues the physical sciences, and blues and white suggest medicine.

8. Effective use of lighting enhances a project. If lights are to be used with the project, care should be taken that

no direct light or glare shines into the eyes of the viewer.

9. Unique and creative arrangements often enhance a project. Many projects lend themselves to a tiered arrangement rather than the conventional flat format.

10. The name and class of the exhibitor should be on the display board.

11. Moveable parts must be firmly attached and safe.

12. All important help should be acknowledged.

13. Certain projects may permit the public to operate the controls. Such controls should be sturdy in construction and should prominently display full instructions for their use.

JUDGING

Judges

The judges for the science fair should be chosen from among the individuals in the community with a background or interest in science. Research scientists and college professors or lecturers might make the best judges it is true, but in many places they will not be available. Any person who can judge the exhibits critically according to the standards you specify is qualified. Their impartiality should have the full confidence of all contestants. Three judges are usually considered a fair and adequate team.

Judging standards

An objective standard for judging should be determined well in advance. A different system of judging may have to be devised for each category in the science fair, but the following criteria–found in the NCERT booklet Organizing Science Fairs— may serve as an example:

Scientific approach (*30 points*): Does the problem involve scientific and methodical thinking? Has there been an orderly analysis of the problem? Does the experimental approach to the problem manifest itself in the collection of data, accuracy of observation and establishing of controls?

Does the project illustrate the cause and effect relationship? Does it show an improved method of better understanding of facts or theories of science?

Originality (*20 points*): Does the exhibit show originality in its planning and execution? Does the exhibit demonstrate new and improved ways of expressing or communicating ideas? Consider ingenious uses of materials and think of collections as being creative if they serve scientific purpose for the exhibitor's class level.

Technical skill and workmanship: (*20 points*) Does the exhibit show evidence of skill, good workmanship, and neat execution? Handling, preparation, mounting of material, and proper labelling should receive adequate attention.

Thoroughness (*10 points*): The exhibit should tell a clear, full but concise story about the project, with proper emphasis on the important items.

Judging will be based on the completeness and accuracy with which the exhibit in presented.

Dramatic value (*10 points*): The exhibit should be attractive and command the attention of visitors, whether laymen or scientists. Are the labels large and the descriptions neatly presented? Is there a progression of the attention of the spectator across or through the exhibit? Is the exhibit more attractive than others in the same field beyond the point of gadgetry?

Personal interview (*10 points*): Does the exhibitor understand the principles? Does the exhibit represent real study and effort? Has his knowledge of science increased due to the project undertaken by the student?

The points mentioned above are only suggestions and may modified be for your science fair in any way that you deem fit.

Instructions for the judges

This may be the first time that the individuals chosen have ever judged at a science fair. They may be aware of the criteria but may be somewhat uncertain as to how to go about their task· Inorder to ensure smooth procedure, the following suggestions may be given to the judges during an orientation period prior to their judging of the exhibits:

1. Talk with and question the exhibitor according to the particular project and circumstances – and not according to a set pattern. Give no credit for originality until you learn the origin and designers of a project, the most difficult and interesting parts of it, etc. Talk with the exhibitors in the absence of other judges if possible in order to have a good understanding of the projects.

2. Under "scientific approach" look for:

   a. Clearly thought and stated conclusions.

   b. Work on problems of good magnitude but not too extensive for completion or attainment of a good stopping point.

   c. Good (if brief) reference to the pertinent literature.

3. Spend as much time as possible to understand each project as fully as you can.

4. A sequence of separate touring, discussion, joint touring, and discussion is recommended.

Efficient operation

A few suggestions may be given here which may help you to overcome some of the trouble spots frequently met with during the judging:

1. It is essential that entrants be aware of judging criteria.

2. Several copies of the judging criteria should be displayed for public view so that visitors may know on what basis the projects are being judged.

3. It is essential that no preliminary showing of the projects be allowed to students or public prior to the judging. Many projects are of such a nature that they can be easily damaged by the jostling crowds. Public viewing of the exhibits should follow the judging.

4. Tabulation forms should be prepared so that the judges' scores can be accurately and quickly tabulated.

Awards

The number and nature of awards should be decided well in advance. This decision will vary from school to school according to the resources available and no strict guidelines can be set down. However, it should be kept in mind that the awards should be chosen as far as possible to suit the requirements of the students concerned. Civic organizations such as the Lions Club or Rotary Club or businesses interested in science, such as medical shops, may be approached for donations for the awards. Certificates should be awarded to all deserving participants. The awards should be divided according to the number of categories in the science fair.

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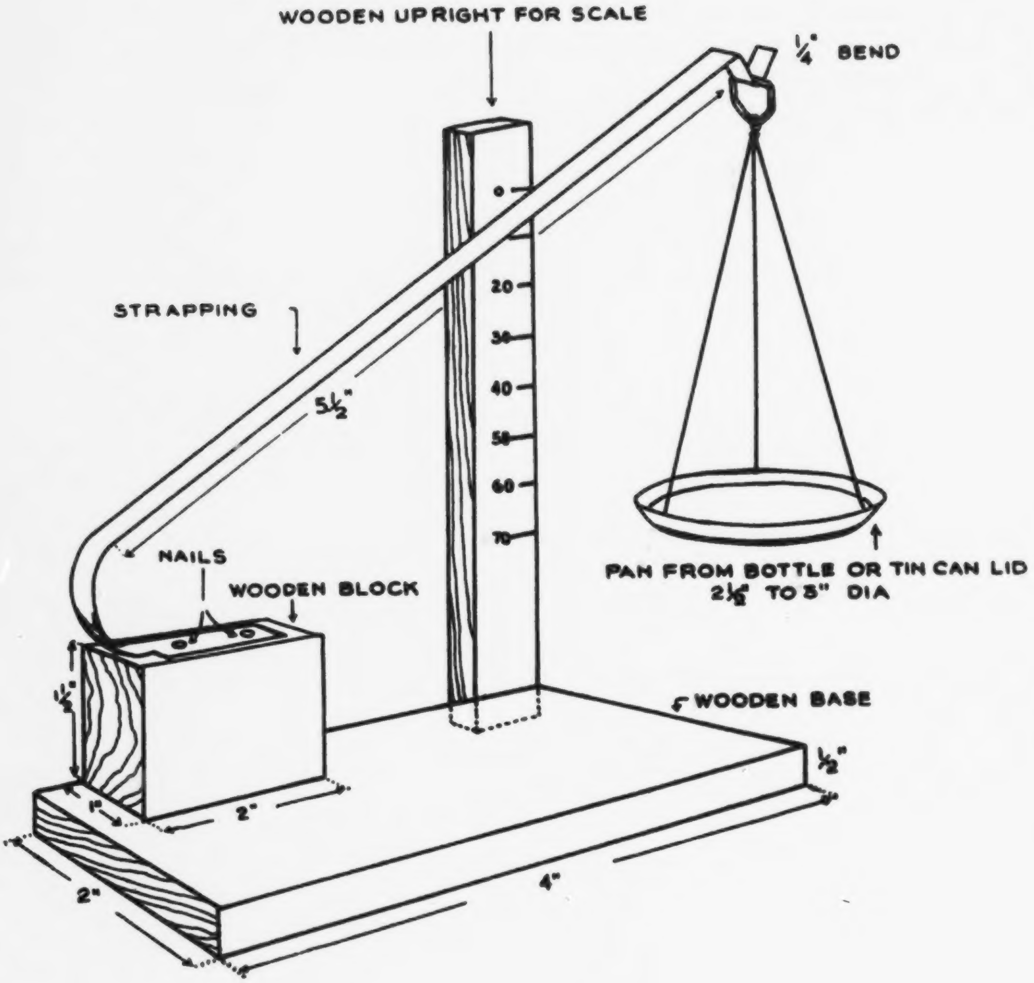
Improvised Apparatus

Every laboratory lacks some pieces of apparatus which are useful in conducting experiments in biology, chemistry or physics. And most laboratories do not have the equipment needed for student participation in these activities.

Since the science cirriculum calls for a wide variety of pieces of apparatus which are not readily available to the teachers in the school, some teachers have taken it upon themselves to supply these articles temporarily until the supply can catch up with the demand. Necessity is the mother of invention and the articles presented here for your consideration are those which have sprung from such a necesity. In fact science has always been in this state, and even in the most advanced countries science teachers are engaged in this type of work.

The articles given in this chapter are meant to introduce you to a wide variety of techniques which you will find useful when you strike out on your own to create a new piece of apparatus. But it is important to stress that this chapter in no way makes an attempt to exhaust all the ideas for apparatus which will be useful either to you in your teaching or for your students during practicals. The chapter was written, however, to give you an idea of the type and extent of things which you can do both easily and cheaply and which remain within the syllabus structure.

STRAPPING BALANCE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70
STRAPPING
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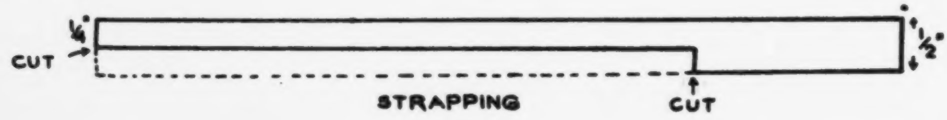
NAILS
WOODEN BLOCK
PAN FROM BOTTLE OR TIN CAN LID
2½" TO 3" DIA
WOODEN BASE
1½"
½"
1"
2"
2"
4"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STRAPPING
CUT

STRAPPING BALANCE

Materials required for construction

1. 1/2" × 2" × 4" wood base.
2. 1½" × 1" × 2" wood block.
3. 1/2" × 1/2" × 5" wood scale.
4. 1/2" wide strapping 7½" long.
5. One tin can lid.
6. String.

Procedure for construction

1. Nail the two wooden pieces (2 and 3 above) to the base as shown in the diagram. Attach a piece of graph paper to the wood scale.

2. Take the strapping and cut it in half for 5½" of its length (see diagram).

3. Bend and fix it to the upper wood block as shown.

4. The last 1/4" of its free end is to be bent in the form of a hook.

5. Make three holes in the lid equidistant from each other and tie the strings assembling as shown in the diagram.

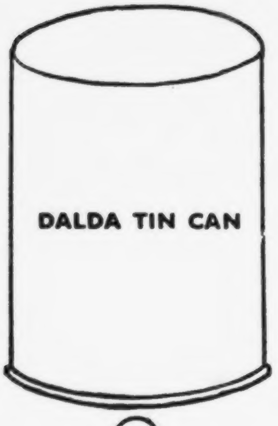
Calibration

1. Put a zero mark on the upright scale piece against the edge of the strapping.
2. Put 10 grams in the pan. Mark the position of the strapping.
3. Continue doing the same up to 70 grams.
4. If a graph paper is used on the scale piece, subdivisions can also be marked.

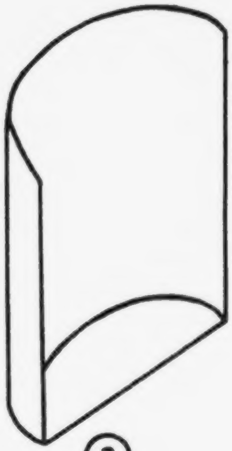
Uses in practicals and demonstrations

This balance is useful only for rough measurements where accuracy is not absolutely essential. It can be useful in making quick measurements during classroom demonstrations and should not be used where accuracy is required for a good demonstration or experiment.

APPARATUS TO SHOW REFRACTION

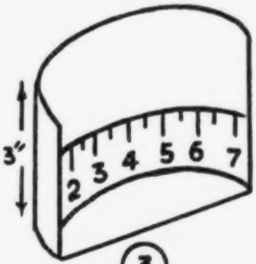

DALDA TIN CAN

①



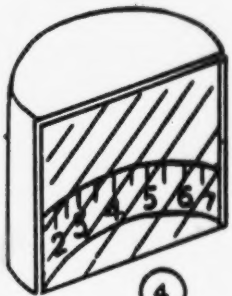
②

CUT THE TIN CAN IN HALF LENGTH-WISE



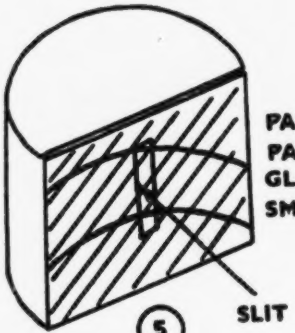
③

CUT THE HALF CAN TO 3" HEIGHT ATTACH A PAPER STRIP TO THE CURVED PART AND MARK ARBITRARY DIVISION UNIT AND COAT WITH WAX



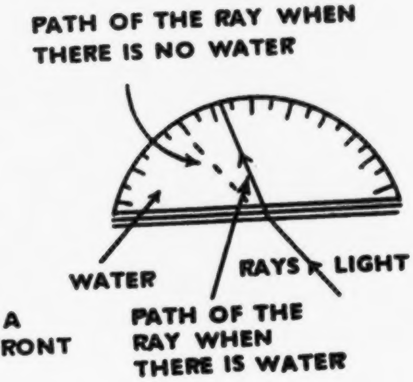
④

BEND THE EDGES TO HOLD A GLASS PLATE IN FRONT SEAL THE JOINTS INSIDE AND OUTSIDE WITH WAX



⑤

PASTE BLACK PAPER TO THE GLASS, LEAVING A SMALL SLIT IN FRONT


PATH OF THE RAY WHEN THERE IS NO WATER
WATER
RAYS ↖ LIGHT
PATH OF THE RAY WHEN THERE IS WATER

TOP-VIEW

APPARATUS TO SHOW REFRACTION

Materials required for construction

1. One Dalda tin.
2. One glass plate.
3. Piece of black paper.
4. Graph paper.
5. Varnish.
6. Candle wax.

Procedure for construction

1. Cut the tin in half lengthwise. Take one of these pieces and cut it so that it stands 3" high.

2. Attach a piece of graph paper marked in equal intervals to the inside wall of the tin along the bottom line. Varnish it.

3. Cut a glass piece to fit the front of the trough.

4. Bend the front edges of the trough slightly inwards to hold the glass piece.

5. Insert the glass piece and make waterproof by sealing it in place by using candle wax.

6. On the outside of the trough, cover the glass piece with a strip of black paper which has a vertical slit along its midline.

Uses in practicals demonstrations

1. To demonstrate the refraction of light through various transparent substances.
2. To measure the refractive index of substances.

Questions for further study

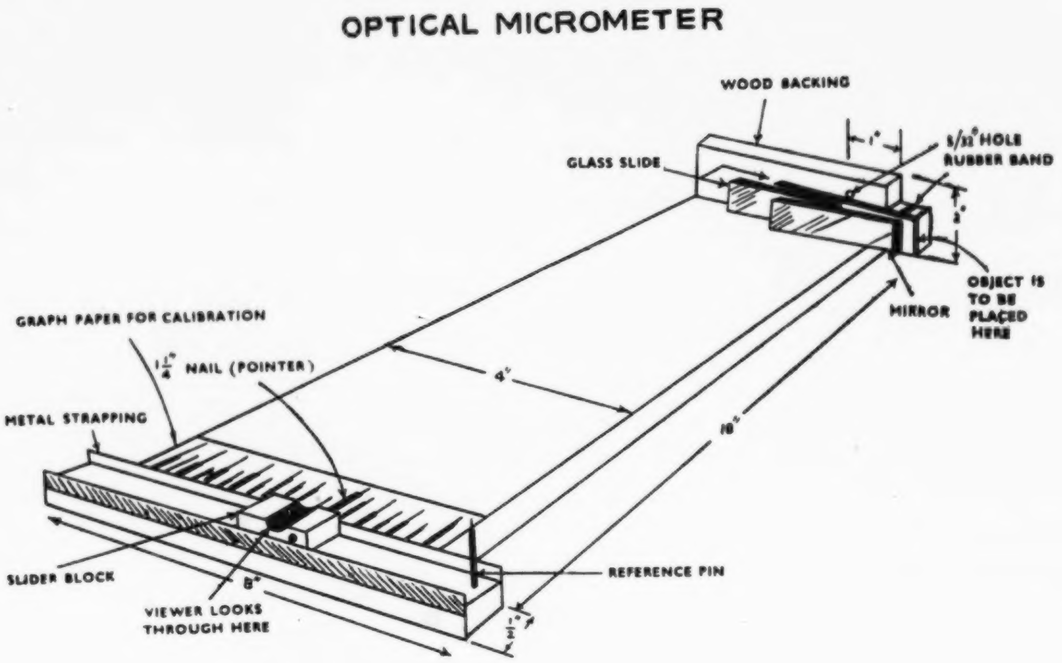
1. Take different transparent liquids in the trough and find their refractive index.

2. Is there any relationship between the refractive index and the density of the substance?

3. How can you demonstrate differences in refraction due to wavelength?

4. What procedures must the student go through to experimentally determine the refractive index of any transparent liquid?

5. Is there a relationship between the molority of a solution and its refractive index?


OPTICAL MICROMETER
WOOD BACKING
GLASS SLIDE
1"
5/32" HOLE
RUBBER BAND
2"
OBJECT IS TO BE PLACED HERE
MIRROR
GRAPH PAPER FOR CALIBRATION
1¼" NAIL (POINTER)
METAL STRAPPING
4"
18"
SLIDER BLOCK
8"
VIEWER LOOKS THROUGH HERE
REFERENCE PIN
½"

OPTICAL MICROMETER

Materials required for construction

1. 1/2" × 1/2" × 2" wood piece.
2. 1/2" × 1/2" × 8" wood piece.
3. 1/2" × 4" × 18" wood piece.
4. 1/4" × 2" × 4½" wood piece.
5. Graph paper.
6. Two thin glass slides 1" × 3" each.
7. One small mirror 1" × 2".
8. Rubber band.
9. 16" of metal strapping.
10. Nails 1¼" long for pointer on the slider block and reference pin. Smaller nails are used to attach wood pieces and strapping.

Procedure for construction

1. Make the slider block from the 1/2" × 1/2" × 2" wood piece. See diagram.

2. Nail the 8" pieces of strapping to each side of the 8" pieces of wood. Be sure about 1/8 of the strapping is above the wood to provide a groove for the slider block.

3. Attach this piece of wood to one of the 4" sides of the 18" piece of wood. See diagram.

4. Take the 1/4" × 2" × 4½" piece and cut 1/2" squares from both top and bottom of one of the 2" sides leaving a 1/2" × 1" "ear" in the middle of the side.

5. Line up glass slides on the top of "ear" even with edge. Drill a 5/32" hole just above the glass slide. Locate this hole about 1" to the left of the surface as shown in the diagram.

6. Attach this piece of wood to one end of the 1/2" × 4" × 18" piece. Paint it black.

7. Fasten one of the slides to the wood with glue.

8. Fasten the second slide to the first. One end of the second slide should line up with the 5/32" hole.

9. Then place the mirror on the slides with its reflecting surface outside. One end of the mirror should line up with the right hand edge of the first slide. Secure it with a rubber band.

10. Cut the head off a large nail and fix it on the right edge of the 8" pieces of wood. See diagram.

11. Attach a strip of graph paper as shown in the diagram. Now the instrument is ready for calibration.

Calibration

1. To find the zero point, look through the groove on the sliding block and move the block until the reflection of the reference pin is seen in the mirror exactly under the drilled hole which is above the glass slide. Mark this point on the graph paper.

2. Measure the thickness of a pad of paper. Then divide the thickness by the number of sheets of paper in the pad thus obtaining the thickness of one sheet.

3. Place one sheet between the mirror and glass slide. Move the slider and align the reference pin under the hole above the glass slide. Mark the position of the pointer on the graph paper.

4. Add sheets of paper one by one and mark the corresponding position of the slider on the graph paper.

5. Each division on the scale is subdivided suitably. This micrometer should be accurate to 0.002".

Uses in practicals and demonstrations

1. To measure the thickness of extremely thin objects.

2. To demonstrate a simple application of the laws of reflection.

Notes on use and construction

After you demonstrate this piece, either in your science club or in your classroom, you may want to ask your student, questions like the following:

1. Explain the principles which govern the functioning of the optical micrometer.

2. What operations must you perform to achieve good accuracy and sensitivity in the apparatus ?

3. The application of the same principle is used in some other experiments in physics. Can you mention them ?

OPTICAL BENCH

Materials required for construction

1. Three 1/2" × 3" × 2" wood bases.
2. Scrap wood for lens height adjustment.
3. 3" × 10" cardboard.
4. Thin aluminium or tin.

Procedure for construction

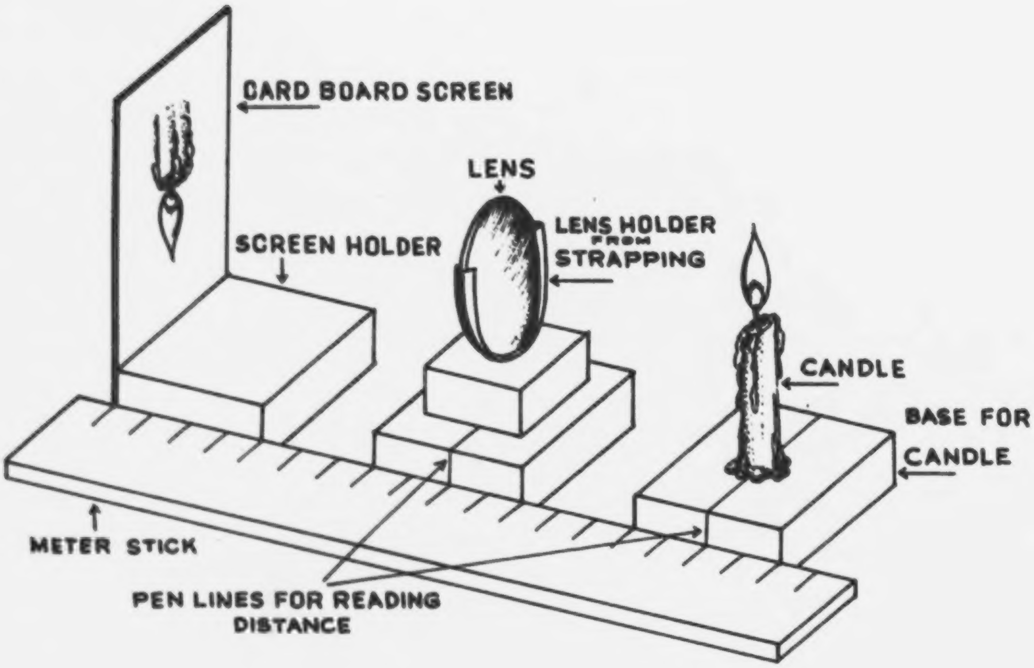
1. Cut the three wood bases and smooth with a rasp and sandpaper.

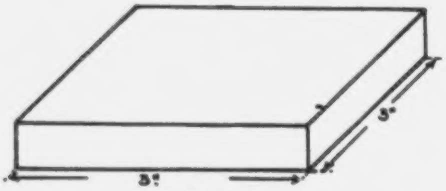
2. *Screen holder* : Apply two coats of varnish and allow to dry. Then attach the 3 × 10" cardboard screen with small tacks or nails.

3. *Candle holder* : With a tri-square and a ball point pen mark a centre line on the top and one side of the base as shown in the diagram.

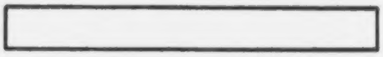
4. *Lens holder* : From scrap wood make a small step on the base 1" high. To this, attach a "U" shaped lens holder bent from strapping as shown in the diagram. This holder should have a "V" shaped cross-section to prevent the lens from slipping. Put tape over the

OPTICAL BENCH

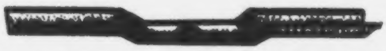

CARD BOARD SCREEN
LENS
LENS HOLDER FROM STRAPPING
SCREEN HOLDER
CANDLE
BASE FOR CANDLE
METER STICK
PEN LINES FOR READING DISTANCE



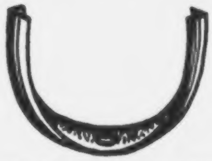
ALL BASES



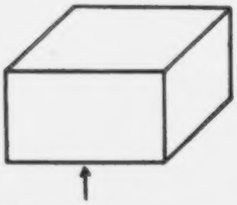
STRAPPING OR TIN



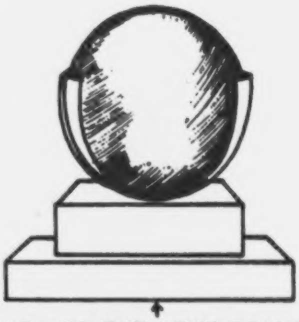
BEND THE STRAPPING AT THE ENDS IN TO V SHAPE



BEND IT LIKE THIS



STAND FOR THE LENS HOLDER



FRONT VIEW OF THE LENS STAND

Strapping to prevent the lens from being scratched.

5. Mark the side of the base with a ball pen to indicate the position of the centre of the lens and apply two coats of varnish.

Uses in practicals and demonstrations

1. To find the focal lengths of small concave mirror and convex lenses.
2. To show the formation of different images when the lens is at different distances from the object.
3. To explore the relationship between "U" and "V".

Questions for further study

1. What improvement can you introduce in the apparatus to get a sharp mage?

2. Can you explain the principle involved in a camera and a magic lantern by using the optical bench?

3. Given another lens and the optical bench, can you construct a telescope and a microscope? What are the conditions which are necessary? How can you find out the conditions using the simple optical bench?

4. Can you make the rays visible so that you can see how they converage and diverge?

5. How can you demonstrate magnification?

6. What is the relationship between the distance of the screen and the amount of magnification?

7. What is the relationship between the focal length of lenses and their magnification?

SPRING BALANCE

Materials required for construction

1. Four feet of steel wire (weena string wire)
2. Bamboo piece 9" long.
3. Two tin pieces for top and bottom.
4. 14 gauge iron wire, 18" long.
5. Test pan made from 2½" diameter tin piece.

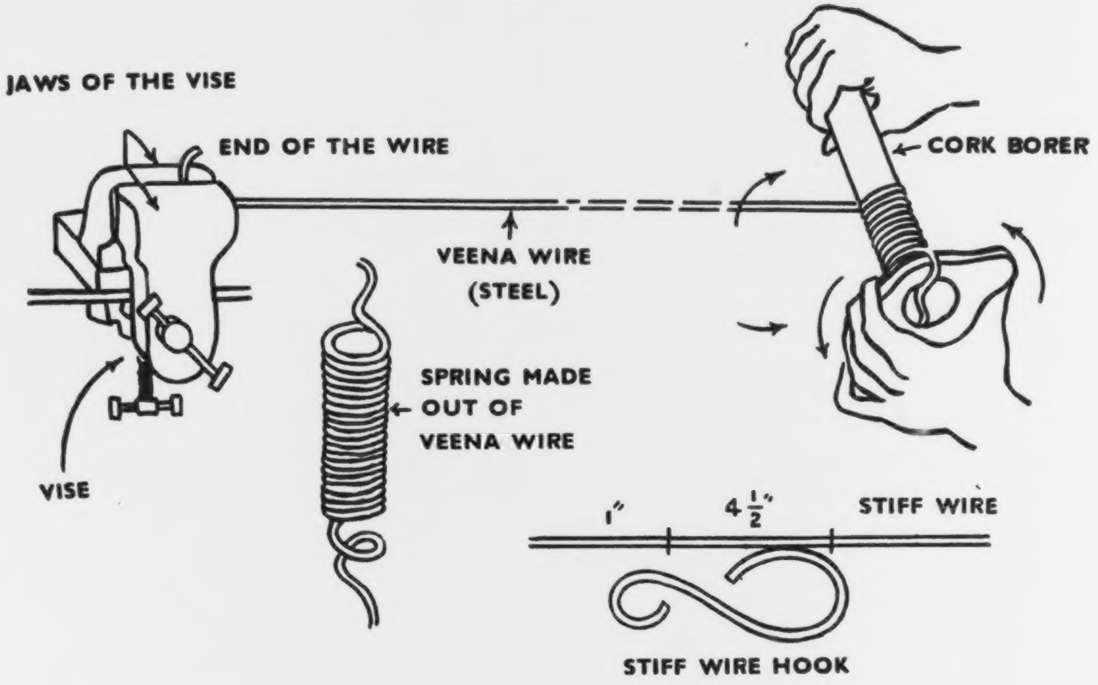
Procedure for construction

1. To wind the wire spring, place the wire and a cylindrical metal object of a suitable diameter (about 1/8") in the jaws of a drill machine. One person turns the drill winding the coils evenly while the other person keeps the wire under tension. When you are finished winding the wire, bend both ends into hooks.

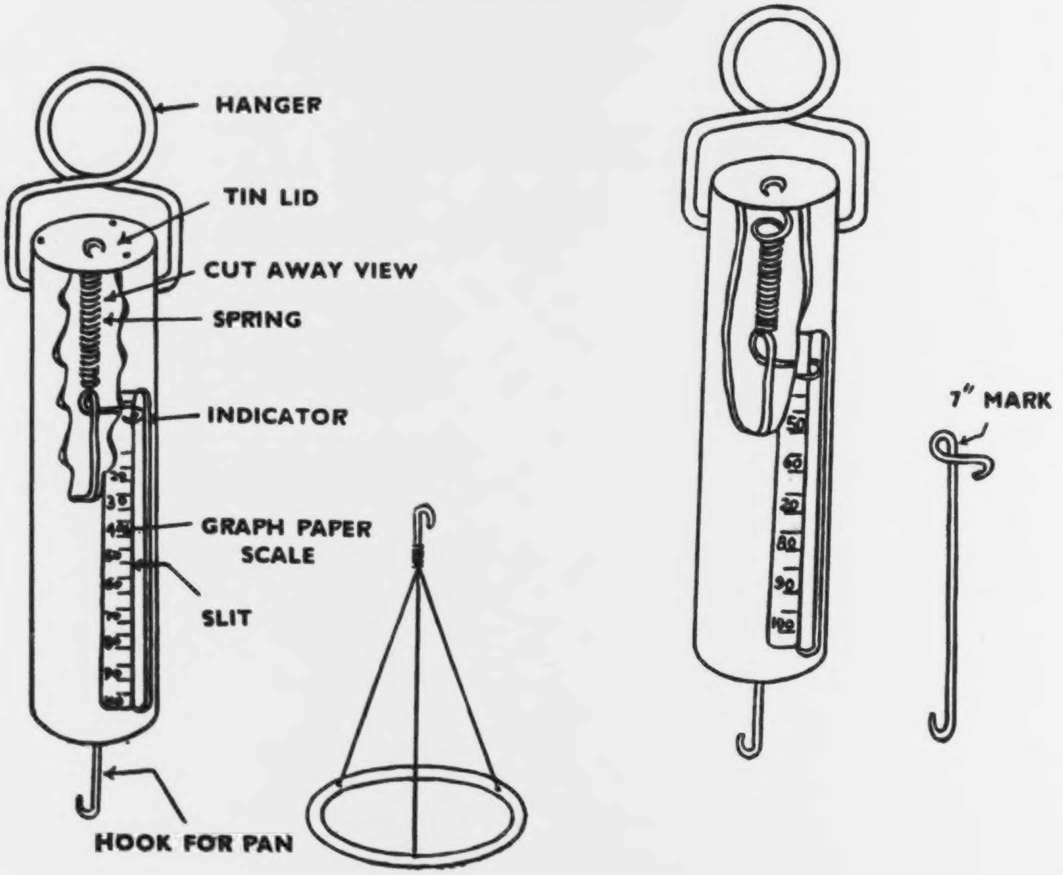
2. Place the top end of the spring at the top of the bamboo tube and mark on the outside of the tube the position of the bottom of the unstretched spring. Then extend the spring to its maximum length without loosing shape and mark this position also. Connect these two points with a straight line.

3. Using the ¼" drill bit, drill holes at the first and second marks that you have just made. Continue drilling holes along the line at 1½" intervals. By using a chisel, you can remove the remaining pieces between the holes being careful that you do not split the bamboo piece in two.

4. For the indicator, bend a 11" piece of iron wire (14 gauge) in the shape illustrated. Tie the spring to the loop


JAWS OF THE VISE
END OF THE WIRE
CORK BORER
VEENA WIRE
(STEEL)
SPRING MADE
OUT OF
VEENA WIRE
VISE
1"
4 1/2"
STIFF WIRE
STIFF WIRE HOOK

SPRING BALANCE


HANGER
TIN LID
CUT AWAY VIEW
SPRING
INDICATOR
GRAPH PAPER
SCALE
SLIT
HOOK FOR PAN
7" MARK
50
60
70
80
90
100

in the wire and insert the spring and wire into the bamboo tube. Tie the other end of the spring to the tin top and fix it to the bamboo tube with small nails. The indicator part of the wire should stick out of the slot. Bend it so that it is parallel to the top of the bamboo.

5. Drill a 3/16" hole in the centre of the piece of tin that will be used for the base. Stick the wire through it and fix the tin to the bamboo with pins. Bend the bottom of the wire into a hook.

6. Glue a strip of graph paper to the bamboo along the slit on the side to which the indicator points.

7. With standard weights, mark five gram divisions on the graph paper. Remember if you use a weighing pan, you must make the proper adjustments in your calculations.

Uses in practicals and demonstrations

1. To illustrate Hook's Law.
2. To show the calibration of the spring balance.
3. To verify and apply Archemedes' principle
4. To measure forces while using the lever apparatus or the inclined plane.

Questions for further study

1. By making springs from equal lengths of wire of different diameters, find the relationship between the distance of the extension and the amount of force required.

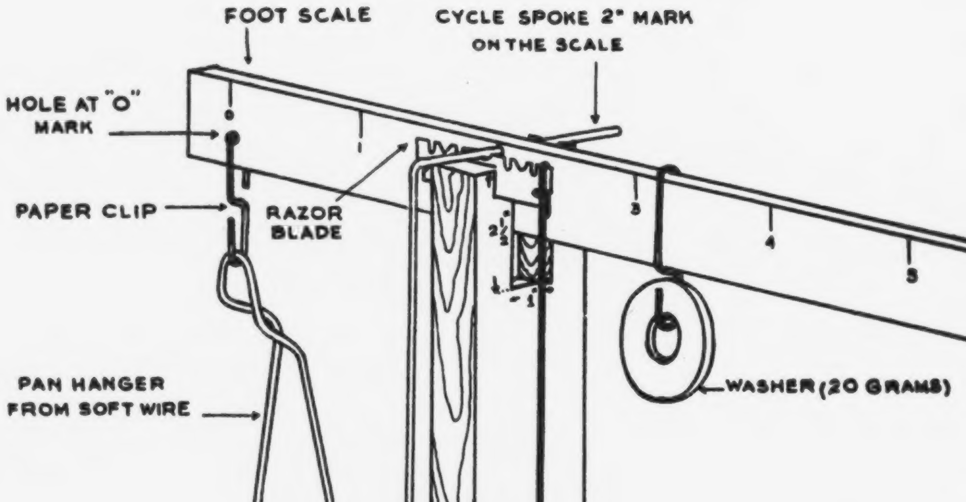
2. Take a rubber band equal in length to the spring balance and investigate how the extension varies in the spring and the rubber band for equal weights.

3. Since air is also an elastic material, how can you design an "air spring balance"?

4. Investigate the percentage error obtained in measuring weights with the "air" spring balance, the rubber band balance, the common balance and the spring balance.

5. By using wires of different materials but with equal diameters and lengths, investigate the nature of extension.

SINGLE PAN BALANCE


FOOT SCALE
CYCLE SPOKE 2" MARK ON THE SCALE
HOLE AT "O" MARK
PAPER CLIP
RAZOR BLADE
1
3
4
5
2½"
1"
WASHER (20 GRAMS)
PAN HANGER FROM SOFT WIRE
PLUMB LINE
¼" BEND
2½"
CARD BOARD SCALE
NUT
6"
5"

SINGLE PAN BALANCE

Material required for construction

1. 1/2" × 5" × 6" wood base.
2. 1/2" × 2½" × 7" wood upright.
3. One wooden foot scale.
4. Two 1/2" × 1/2" × 2½" wood. supports.
5. One cycle spoke.
6. 12½" of heavy wire.
7. One razor blade.
8. 3" × 3" tin piece.
9. Paper clips.
10. Washer or any other weight of 20 gms.
11. Thick broom stick.
12. Cardboard.

Procedure for construction

1. Cut and sand all wood pieces.

2. Cut a notch 2" × 1", 1¼ from either edge of the 2½" side of the 1/2" × 2½" × 7" wood upright.

3. Varnish all wood pieces.

4. Drill a small hole at the 2" mark of the foot scale just above the mid-longitudinal line.

5. Drill a 1/10" hole at the zero mark just below the mid-longitudinal line of the foot scale.

6. Attach the upright to the base exactly at the base's centre. This is 2½" from either edge of the 5" side.

7. Nail the supports on each side of the bottom of the upright.

8. Push a 4" piece of a cycle spoke through the hole at the 2" mark on the foot scale. Secure it with sealing wax.

9. Attach the broomstick to the end of the cycle spoke which is at the front of the scaled part of the foot scale.

10. Cut notches in the two limbs of the upright about 1 5" deep. See diagram.

11. Insert the razor blades into these slits and secure with sealing wax.

12. Straighten a paperclip, as shown in the diagram, to form a hook for the pan. Hang this hook from the hole at the zero mark on the foot scale.

13. Bend the heavy wire to form a pan hanger. See diagram.

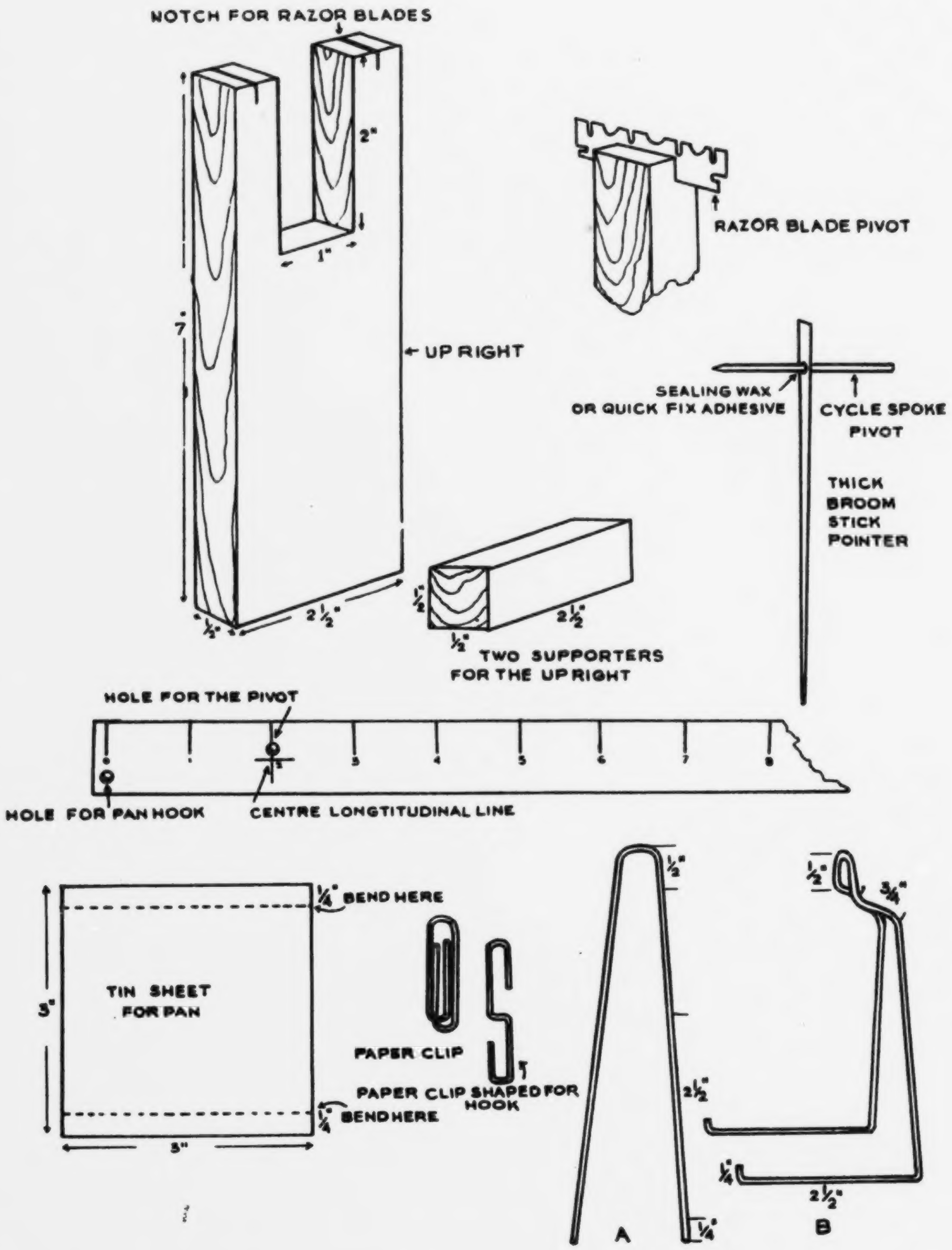
14. From the tin piece, make a pan like that depicted in the diagram.

15. Attach the cardboard scale to the upright.

16. Balance the pan with a heavy washer kept at the 4" mark on the free arm of the scale.

17. Suspend a small washer on a thread from the edge of the razor blade.

SINGLE PAN BALANCE PARTS


NOTCH FOR RAZOR BLADES
2"
1"
7"
← UP RIGHT
½"
2½"
RAZOR BLADE PIVOT
SEALING WAX OR QUICK FIX ADHESIVE
CYCLE SPOKE PIVOT
THICK BROOM STICK POINTER
½"
2½"
½"
TWO SUPPORTERS FOR THE UP RIGHT
HOLE FOR THE PIVOT
0
1
2
3
4
5
6
7
8
HOLE FOR PAN HOOK
CENTRE LONGTITUDINAL LINE
¼" BEND HERE
TIN SHEET FOR PAN
3"
3"
¼" BEND HERE
PAPER CLIP
PAPER CLIP SHAPED FOR HOOK
½"
2½"
¼"
A
½"
¾"
¼"
2½"
B

Calibration

1. Glue a white slip of paper on the free arm of the scale.

2. Add 10 grams to the pan· Move the washer along the arm until it balances. Mark the position as "10".

3. Add 20 grams to the pan. Move the washer until the beam balances and mark it as "20".

4. Continne calibrating the rest of the beam in the same manner.

Uses in practicals and demonstrations

This piece of apparatus is useful when weight boxes are not easily available or not available in sufficient number for a large group of students. It provides cheap, quick and easy relief for such situations. It is also useful as a good exercise in using the principles of levers.

LEVER APPARATUS

Materials required for construction

1. 1/2" × 1/2 × 24" wood bar.
2. 1/2" × 3" × 4" wood base (from 3" stock).
3. Two 1/2" × 1/2" × 6" wood uprights.
4. 1/2" × 1/2" stock wood Brace piece (see 4 below).
5. One razor blade.

Procedure for construction

1. Cut and sand the wooden pieces in 1, 2 and 3 above.

2. Make two cut-outs on the 4" sides of the base to receive the uprights. Make the cross-grain cuts with the saw and remove the remaining piece with the chisel.

3. From 1/2" × 1/2" stock cut a brace piece of the proper length to fit between the uprights. Nail it in place approximately 1" from the top of the uprights.

4. Find the centre of the bar and drill a hole ABOVE the centre of gravity which will fit the 3" piece of wire. In-

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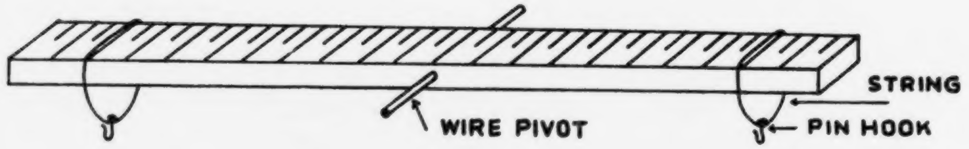
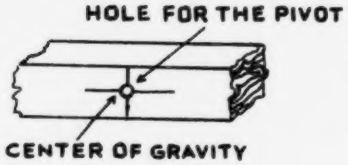
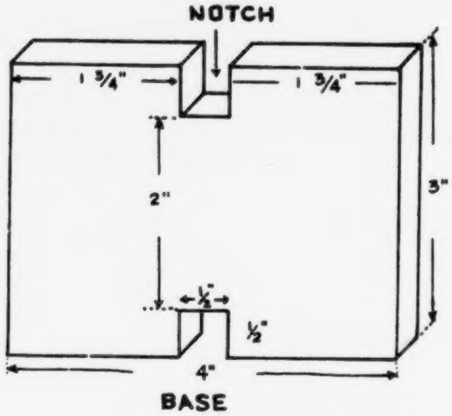
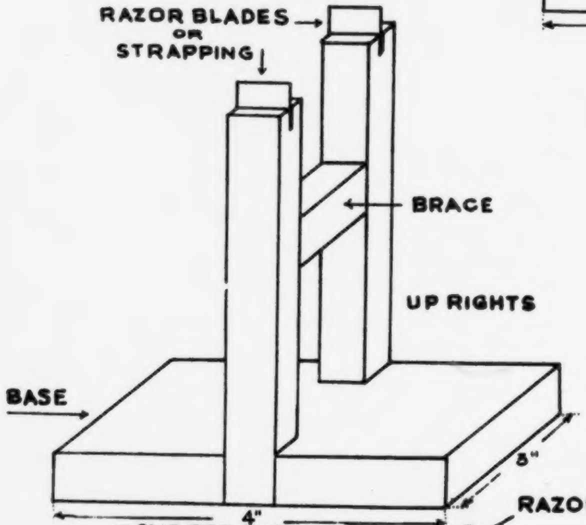
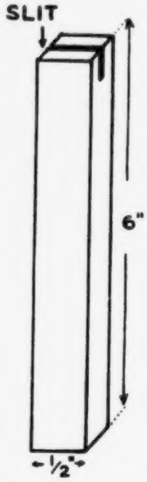
LEVER APPARATUS

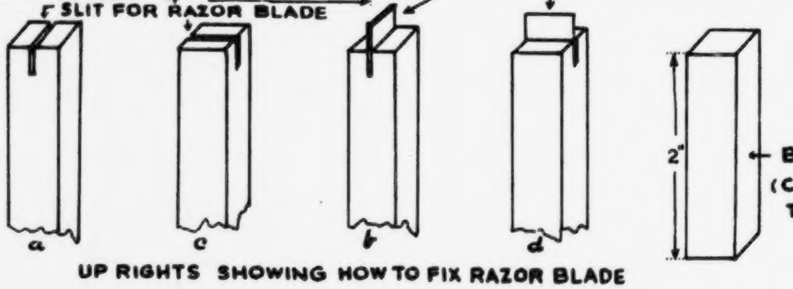

STRING
WIRE PIVOT
PIN HOOK


HOLE FOR THE PIVOT
CENTER OF GRAVITY

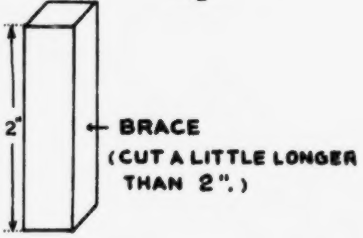

NOTCH
1 3/4"
1 3/4"
2"
3"
1/4"
1/2"
4"
BASE


RAZOR BLADES OR STRAPPING
BRACE
UP RIGHTS
BASE
3"
4"




SLIT FOR RAZOR BLADE
RAZOR BLADE OR STRAPPING
a
c
b
d

UP RIGHTS SHOWING HOW TO FIX RAZOR BLADE


2"
BRACE
(CUT A LITTLE LONGER THAN 2".)

sert the wire and make it fit tightly by using sealing wax.

5. Mark and number the bar in centimeters beginning from the centre and proceeding toward each end. The markings should be finished with a dark ball point pen.

6. Varnish all the wood pieces taking care that no varnish gets on the razor blade or the wire point. If, after varnishing, the bar does not balance exactly, attach a pin or a tack on the underneath side of the appropriate arm to make it level.

7. Weight holders may be made by attaching thread loops around the bar and hanging bent pin hooks from them.

8. Cut narrow slits in one end of each upright and insert the piece of razor blade into the slots fixing them to the upright with either glue or sealing wax and in such a way that they are both parallel and level. Nail the uprights to the base.

Uses in practicals and demonstrations

1. To demonstrate the principle of moments.
2. To demonstrate the three types of levers.
3. To do quantitative experiments on the lever.

Questions for further study

1. Why wouldn't the lever apparatus balance if the arm were placed upside down?

2. How can you use the apparatus as a equal arm balance?

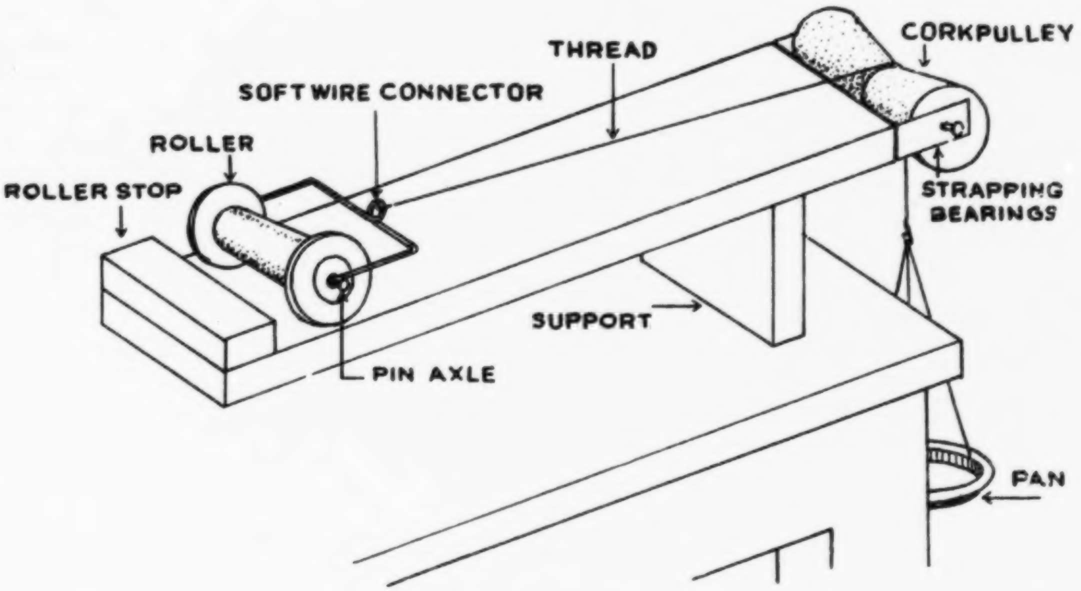
3. How can you improve the sensitivity of such a balance?

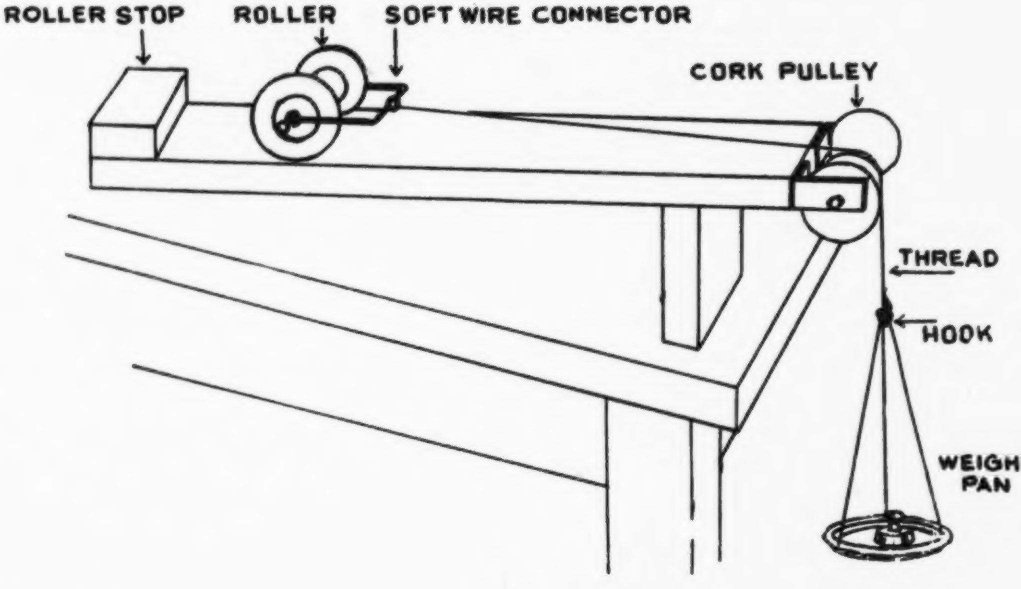
4. How would you demonstrate the first law of levers? Draw a graph of load vs. power arm. Draw conclusions.

5. How would you demonstrate the second law of levers? Draw a graph of load arm vs. power. What conclusions can you come to?

6. How would you demonstrate the third law of levers? Draw a graph of load arm vs. power. What conclusions can you draw?

INCLINED PLANE


CORKPULLEY
THREAD
SOFT WIRE CONNECTOR
ROLLER
ROLLER STOP
STRAPPING BEARINGS
SUPPORT
PIN AXLE
PAN


ROLLER STOP
ROLLER
SOFT WIRE CONNECTOR
CORK PULLEY
THREAD
HOOK
WEIGHT PAN

INCLINED PLANE

Materials required for construction

1. 1/2" × 4" × 24" wood plance.
2. 1/2" × 4" × 4" upright support.
3. Scrap 4" stock 1/2" to 1" long for end stop.
4. 8" of flexible copper wire.
5. 2½" long pipe for roller.
6. Four 1" corks.
7. Four straight pins.
8. Two 2" pieces of strapping.

Procedure for construction

1. Cut and sand carefully the 24" wood plane.

2. Cut the upright support piece and nail it to the plane approximately 1" from the end. Nail the roller stop piece at the other end. Apply two coats of varnish to this assembly and allow to dry.

3. *Roller*: Push corks into the ends of the 2½" piece of pipe. Put straight pins into the centre of these corks leaving approximately 1/4" sticking out. Make the connector for the roller from flexible copper wire and see the diagram for the proper shape. If the roller isn't heavy enough, you may fill the pipe with either lead shot or sand. Caution: If you fill the roller with sand, make sure that it is packed tightly leaving no empty spaces.

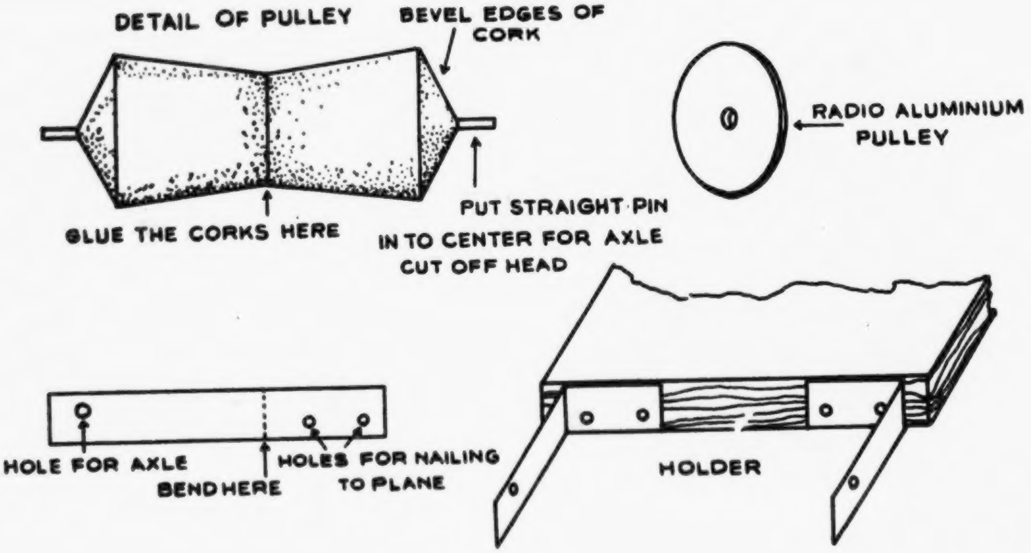
4. *Pulley*: Stick the small end of two corks together using sealing wax being careful to match the ends evenly. Push a straight pin into the centre of each cork leaving 3/8" to 1/2" sticking out. Cut-off the heads. Make two pulley holders from strapping, shaping them as shown in the diagram. Fix them to the centre of the end of the plane with just enough space between them to fit in the cork pulley. The cork pulley should rotate freely and not touch the pulley holders. For this reason, the cork ends of the cork pulley should be filed as illustrated.

5. A weight pan may be made from scrap tin (for instance from the top of a kerosene tin). Use light thread and a hook made from a straight pin to attach the weight pan to the roller assembly.

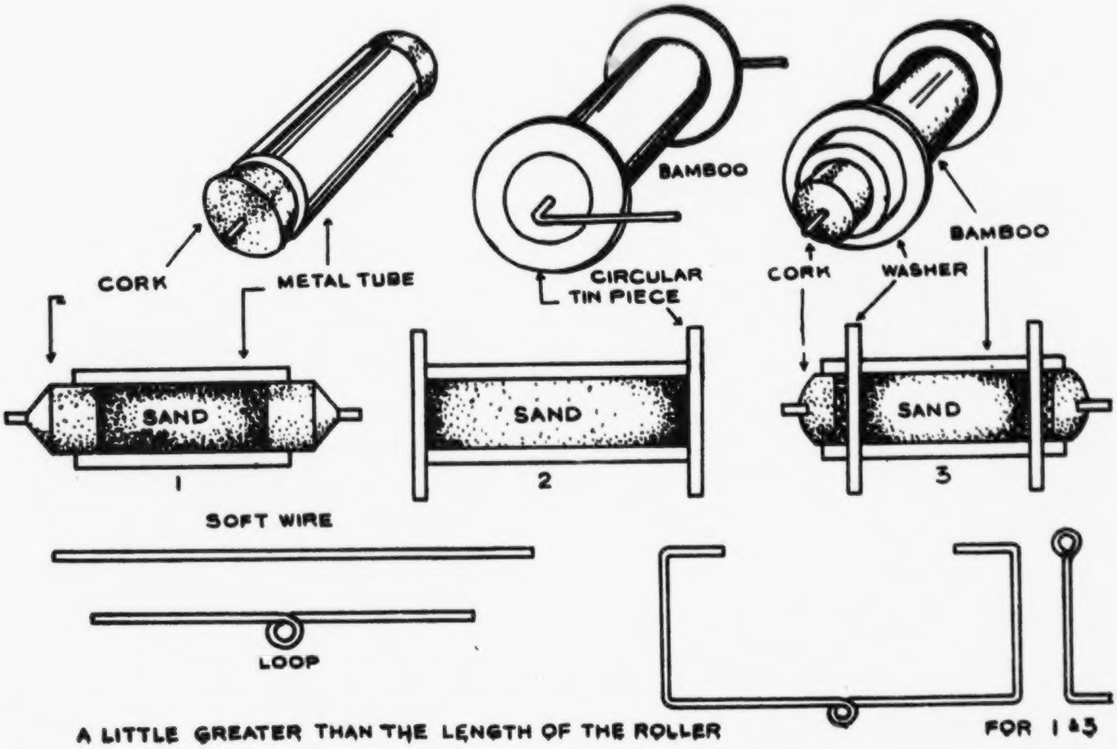
Uses in practicals and demonstrations

1. To demonstrate the working principle of an inclined plane using the spring balance.
2. To find the relationship between the ratio of weight and power to the length and height of the plane.
3. To illustrate quantitatively and qualitatively the mechanical advantage of the inclined plane.

DETAIL OF PULLEY and PULLEY HOLDER


DETAIL OF PULLEY
BEVEL EDGES OF CORK
RADIO ALUMINIUM PULLEY
GLUE THE CORKS HERE
PUT STRAIGHT PIN IN TO CENTER FOR AXLE CUT OFF HEAD
HOLE FOR AXLE
BEND HERE
HOLES FOR NAILING TO PLANE
HOLDER

ROLLERS


CORK
METAL TUBE
BAMBOO
CIRCULAR TIN PIECE
CORK
WASHER
BAMBOO
SAND
SAND
SAND
1
2
3
SOFT WIRE
LOOP
A LITTLE GREATER THAN THE LENGTH OF THE ROLLER
FOR 1 & 3

Questions for further study

1. Derive experimentally the formula for the mechanical advantage of the inclined plane.

2. Find the relationship between the ratio of weight and power to the length and height of the plane.

3. Why should the pulley be made out of cork or light metal?

4. Where can you apply the principle of the inclined plane?

5 You will see sign boards by the side of the railway track–1/100 or 1/1000 or 1/5 etc. What do they signify?

6. How can you achieve maximum mechanical advantage in laying a road uphill?

7. What is the relationship between the angle of the plane and the acceleration of the pulley when it is falling?

CELL HOLDER AND SWITCH

Materials required for construction

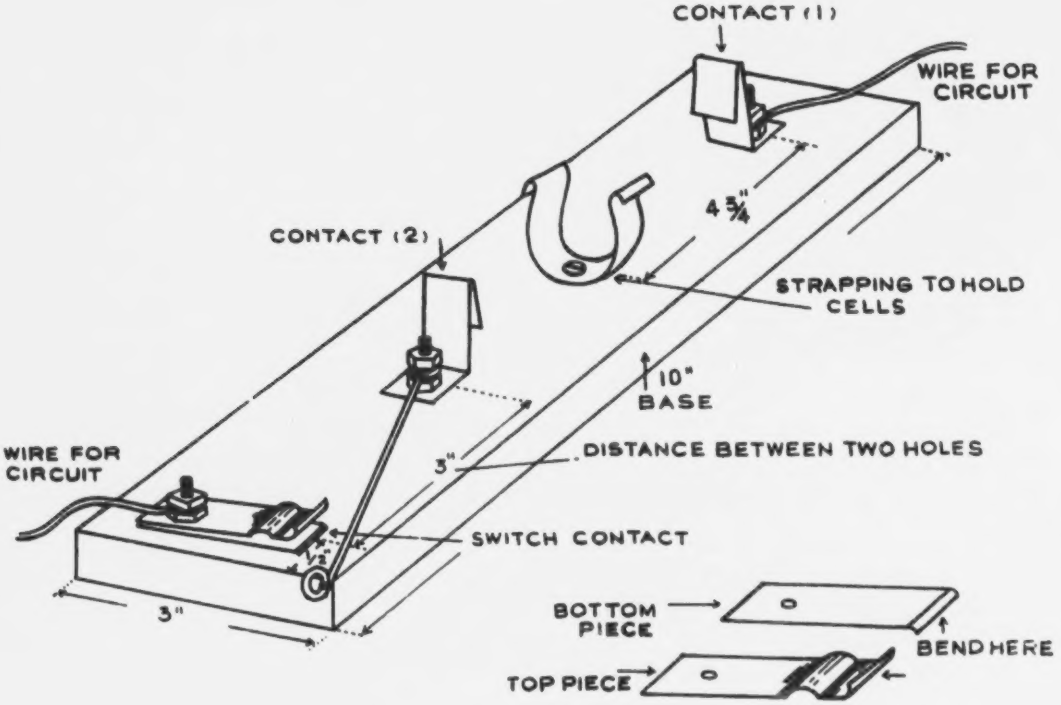
1. 1/2" × 3" × 10" wood base
2. Four 2" pieces of metal strapping.
3. Three bolts with six nuts and six washers.
4. 4½" × 5" piece of heavy paper.
5. 4" piece of medium wire.

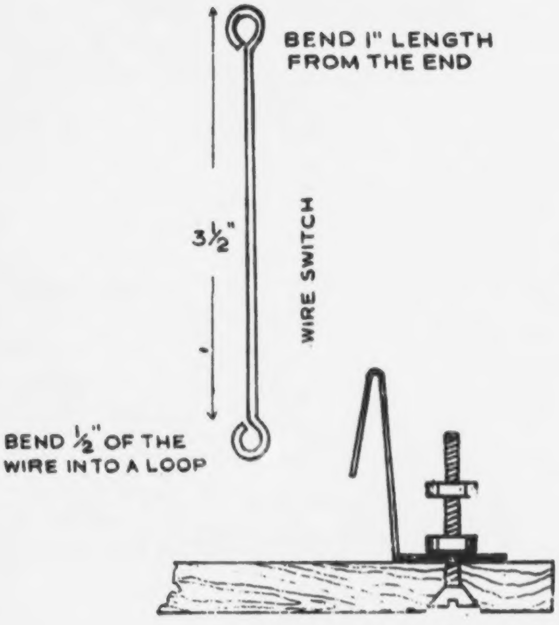
Procedure for construction

1. Bend two of the pieces of metal strapping almost into right angles, with the apex of the angle at the centre.

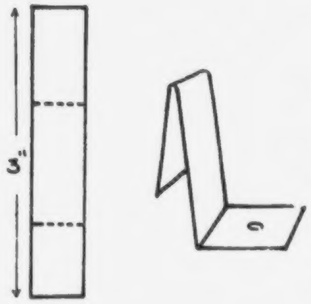
2. Drill holes in one end of each to receive the small bolts.

CELL HOLDER *and* SWITCH


CONTACT (1)
WIRE FOR CIRCUIT
4 3/4"
CONTACT (2)
STRAPPING TO HOLD CELLS
10" BASE
WIRE FOR CIRCUIT
3"
DISTANCE BETWEEN TWO HOLES
SWITCH CONTACT
1/2"
3"
BOTTOM PIECE
BEND HERE
TOP PIECE


BEND 1" LENGTH FROM THE END
3½"
WIRE SWITCH
BEND ½" OF THE WIRE IN TO A LOOP

HOW TO FIX A CONTACT



STRAPPING CONTACTS
FIX THEM TO THE BASE
WITH ONE NUT AND BOLT. USE THE
OTHER NUT FOR FIXING THE WIRE LEAD.

3. Beginning at one end of the base, measure off ¾". From this point measure off 4¾, the length of two standard "D" size cells. Drill two holes in the base so that the two "L" shaped contacts may be attached by the holes leaving 4¾" between them.

4. Approximately 2" from the second contact, drill another hole in the base to attach the contact for the switch. This contact is made from a short, straight piece of strapping bent up at one end. It should be drilled to receive a small bolt.

5. Bend the switch handle from large, stiff wire. The fixed end of the switch is to be attached to the base with the same bolt used to hold the second "L" shaped contact.

6. Apply two coats of varnish to the base.

7. When dry, attach the metal pieces to the board with three small bolts. The heads of the bolts should be on the bottom side of the base and a large drill may be used to make a hole to counter-sink the bolt heads.

8. Wrap a heavy piece of paper around the two cells, making sure it does not come all the way to the ends. Secure the paper with a small piece of adhesive plaster. This tube will keep the cells from slipping out of the holder.

9. Slight adjustment of the " L " shaped contacts may be necessary to get a good connection.

Uses in practicals and demonstrations

To provide convenient mounting and terminals for two standard torch cells and a switch for connecting them in a circuit.

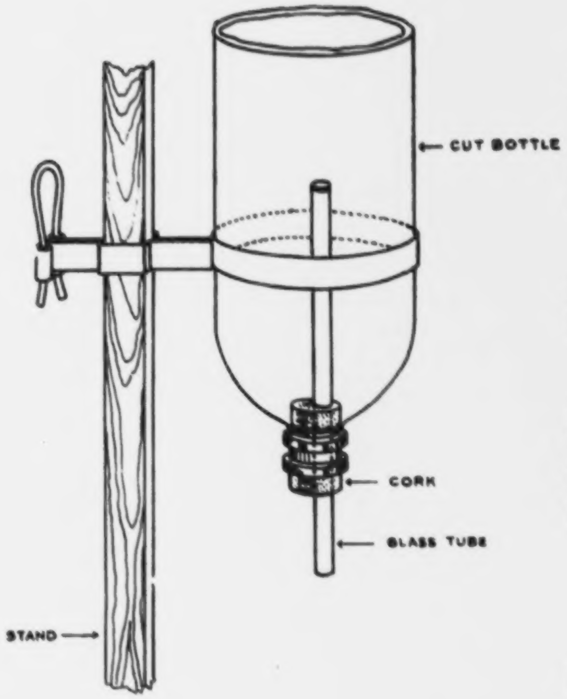
Notes on use and constructin

Be sure that you sand the contact surfaces before use. Rust will build up quickly and insulate these surfaces. It is best if after use you wipe all surfaces clean. Rust will build up much less quickly if you keep these surfaces free from perspiration.

OVERFLOW JAR

Materials required for construction

1. One squash bottle.
2. One cork to fit the bottle's mouth.
3. 8" of glass tubing.



OVER FLOW JAR

Procedure for construction

1. Cut off the bottom of the bottle.

2. Bore a hole in the cork to one side, not at the centre.

3. Fit the cork to the neck of the bottle.

4. Introduce the glass tube in it. The end part of the tube that is inside the bottle should be 1/2" below the cut bottom.

Uses in practicals and demonstrations

1. To measure the volume of irregular bodies which don't fit into the graduated cylinder.

2. To collect the water displaced by bodies in experiments concerning the laws of flotation or Archimedes' principle.

RAO'S BOTTLE

Materials required for construction

1. A bottle with a narrow neck.
2. One–holed cork to fit the neck of the bottle.
3. One glass tube, longer than the height of the bottle.
4. Turpentine and camphor mixture.

Procedure for construction

1. Mark three equidistant points in a line, parallel to the longitudinal axis of the bottle. See diagram.

2 Put a drop of turpentine camphor mixture on one mark.

3. Chip off the end of a triangular file.

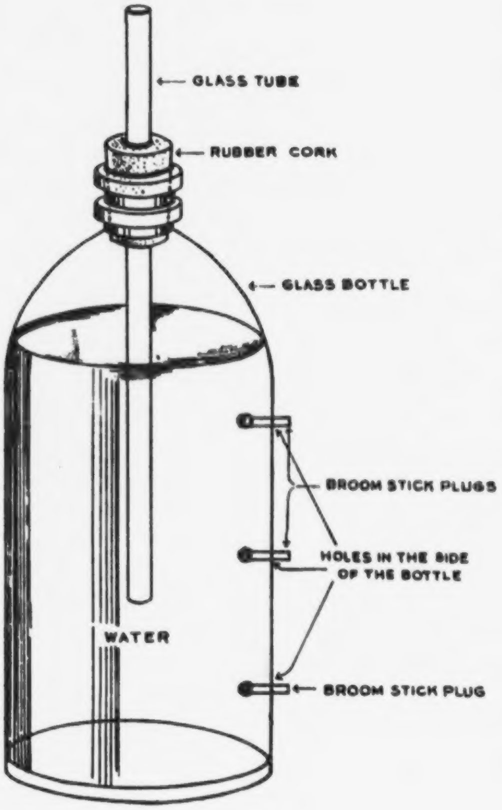
4. Take the small piece and use one of its pointed corners to bore a hole where you placed the turpentine camphor mixture.

5. Slowly apply pressure and drill until a very small hole is made in the bottle. Its diameter should be approximately 1 mm.

6. Repeat the procedure for the other two holes.

7. Wash the bottle and put pieces of broomsticks in the holes to serve as plugs.

RAO'S BOTTLE



Uses in practicals and demonstrations

1 This piece provides a constant flow of water and can be used in conjunction with the water timer.

2. It also is a useful demonstration when teaching pressure because when the three holes are unpluged simultaneously, water will flow out hole "C". There will be no flow out hole "B" and air will be taken in, bubbling through the water at hole "A".

Notes on use and construction

Ask your students what will happen if you unplug hole "A", hole "B", and hole "C"? why? After you get their opinions and reasons, try the following experiment. If you unplug hole "C" water will flow out, due to the outward pressure of the column at point "C" (which is greater than the atmospheric pressure inwards). If you unplug only hole "B", there should be no motion; this is because water flowing out hole "B" must be replaced in the bottle by water from the glass tube. But if this happens, the column of water inside the glass tube is shorter than the column outside the tube. The upward pressure at the bottom of the tube (resulting from the column of water in the bottle) would be greater than the downward pressure from the column inside the tube, forcing the water in the tube back up· Therefore, water cannot flow out "B". If you unplug only "A" there will also be no flow.This is for the same reason–any loss of water through "A" must force a drop of water level in the tube creating the loss of downward pressure at the bottom of the tube· Since the upward water pressure at this point remains constant due to the column of water in the bottle, water cannot come out from the tube. Thus there is no leakage at "A".

COMMON BALANCE

"EXPLODED" 3 DIMENSIONAL VIEW

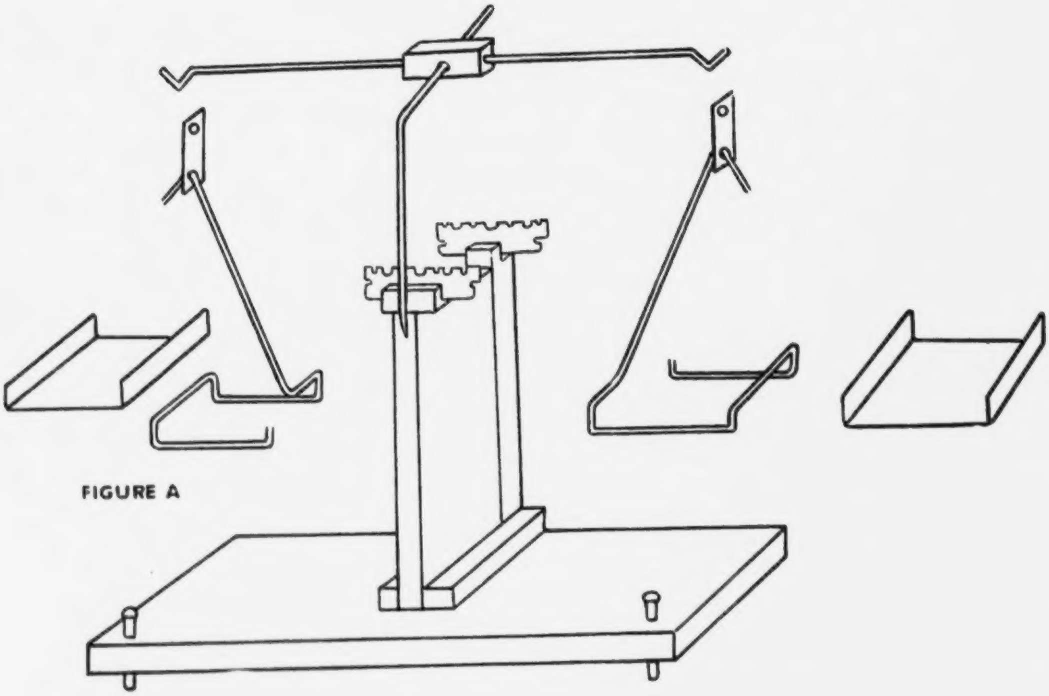


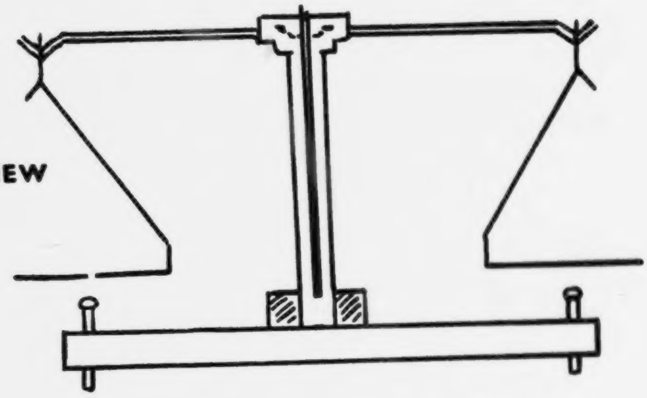
FIGURE A

THE COMMON BALANCE

Materials required for construction

1. 1" × 4" × 10" wood piece.
2. 1"×3 × 7½" wood piece.
3. Two 1" × 1" × 3" (approximate) wood pieces.
4. 1/2" × 1" × 2½" wood piece.
5. Two cycle spokes.
6. One large sewing needle.
7. One razor blade.
8. Tin.
9. 16 gauge iron wire.
10. Two 3/16" bolts 1½" long.
11. One broomstick.

COMMON BALANCE



“FLAT” FRONT VIEW

FIGURE B

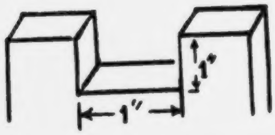


FIGURE C

FIGURE D

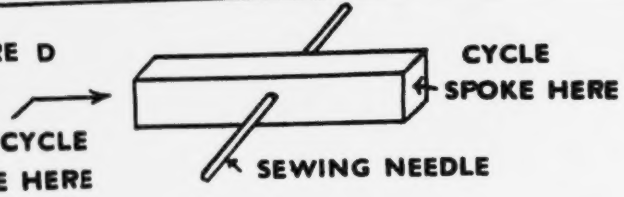

CYCLE
SPOKE HERE
ONE CYCLE
SPOKE HERE
SEWING NEEDLE

FIGURE E

(BALANCE ARMS)

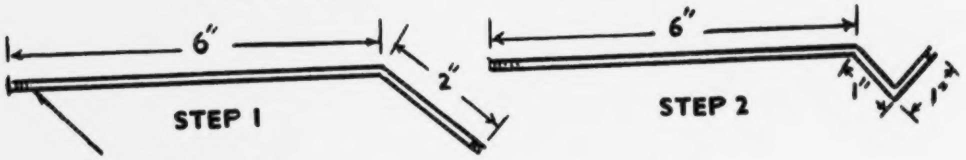
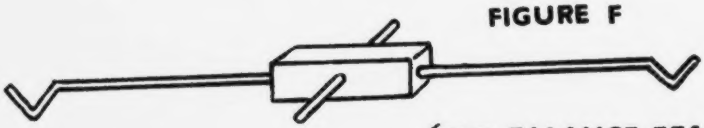

6"
2"
STEP I
SCREW THREAD
6"
1"
1"
STEP 2

FIGURE F



(THE BALANCE BEAM)

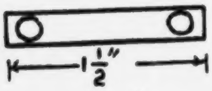


FIGURE G

Procedure for construction

1. Cut and sand the wood pieces. Take the upright piece (1″×3″×7½″) and cut a notch in the centre of one end. The notch should be 1″ deep and 1″ wide.

2. Nail the upright across the centre of the base, such that the back edge of the upright meets the back edge of the base. This should leave about 1″ between the front of the upright and the front edge of the base.

3. Fasten the 1″×1″×3″ pieces as braces on each side of the upright. (See diagram and check the accuracy of your work to this point).

4. Varnish the assembly.

5. In the 1/2″ × 1″ × 2½″ piece, drill a hole the proper size to fit the sewing needle very tightly. This hole should be just above the centre of gravity of the wood piece. The closer the fulcrum (that is, the needle) is to the centre of gravity, the more sensitive will be the balance. This hole also must be exactly perpendicular (normal) to the 1″ × 2½″ faces of the wood piece. (See diagram)

6. In the ends of this same piece in a line just slightly lower than the fulcrum, drill two holes with a pointed piece of cycle spoke (which can be sharpened with the triangular file). Make the holes each about 3/4″ deep. Into these holes you will screw the arms (the two cycle spokes) of the balance beam. (See diagram).

7. From each cycle spoke cut an 8″ length, making sure the threaded end of the spokes are part of this 8″ length. Bend each piece as shown in the diagram.

8. Screw these two "arms" into the holes in the ends of the fulcrum block. Make sure that the points of suspension of the weight pans are exactly equal lengths from the needle fulcrum. (You can test for this after the balance is completed.)

9 Cut two tin pieces into the "I" shape shown (see diagram). Make each one about 1½″ long and 1/2″ wide Then drill two 3/16″ holes at each end of both pieces.

10. Bend two lengths of wire, each 16″ long, as shown in the diagram. These bent wires will serve as weight pan holders.

11. Cut two 3½′ squares from a tin sheet. Bend each as shown in the diagram. These weight pans should fit snugly into the wire pan holders.

12. Cut a razor blade in half, lengthwise.

13. Fix each half blade into the top of the upright. Be sure the blades are no farther apart than the length of the needle fulcrum. Also the centre notch of each blade must be directly in line with the other across the 1″ × 11″ notch in the upright.

14. Drill 3/16″ holes near the front left and front right corners of the base. Keep each hole about 1/2″ from the ends and front edge of the base. Widen the holes at the bottom allowing the nuts to be countersunk and held in place. These can be kept in place by nailing tin sheets over them. By turning the bolts in these two nuts you can adjust the balance so that it is level.

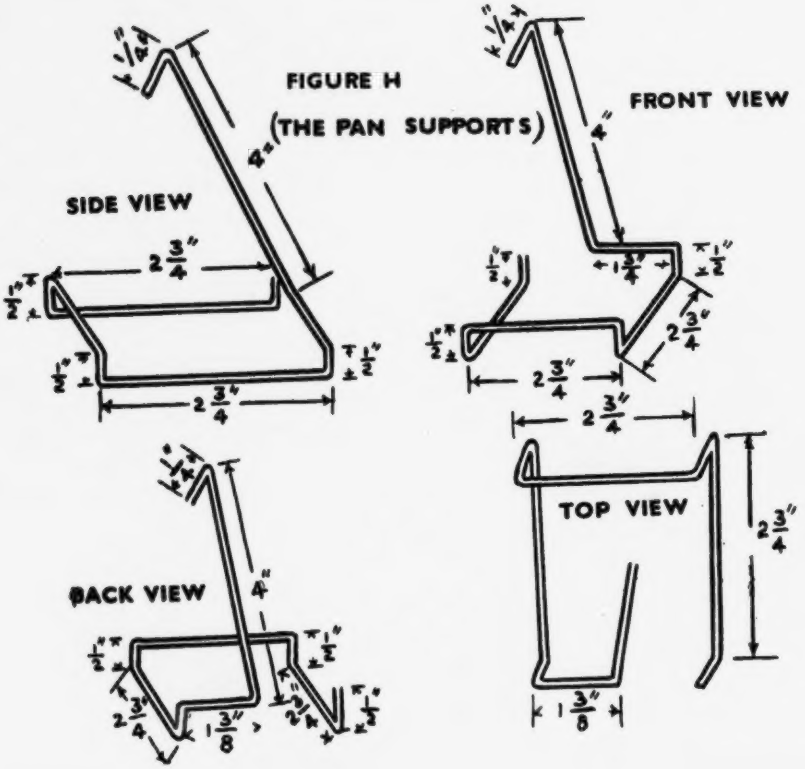
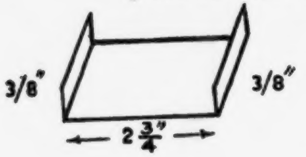

SIDE VIEW
FRONT VIEW
BACK VIEW
TOP VIEW
1/4"
4"
2 3/4"
1/2"
1 3/4"
1 3/8"

FIGURE H

(THE PAN SUPPORTS)

FIGURE I

(THE WEIGHT PAN)



(FULCRUM SUPPORT)

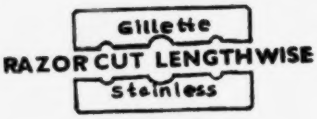
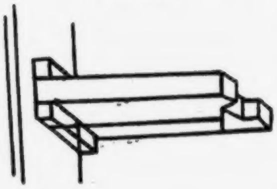

Gillette
RAZOR CUT LENGTHWISE
Stainless

FIGURE J

FIGURE M


UPRIGHT WITH
NEEDLE PLUMB LINE

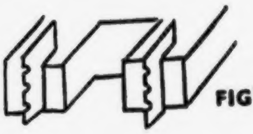

TOP VIEW
UPRIGHT WITH
RAZOR BLADES

FIGURE K

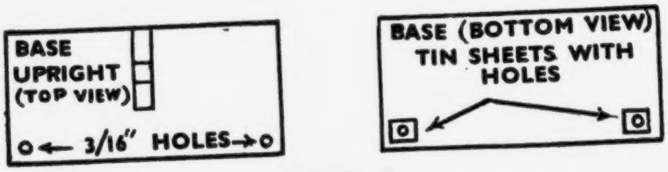

BASE
UPRIGHT
(TOP VIEW)
3/16" HOLES
BASE (BOTTOM VIEW)
TIN SHEETS WITH
HOLES

FIGURE L

15. For the third leg of the base, hammer a nail into the bottom of the base at the centre rear of the base. Leave about 1/2" of the nail free to act as a leg.

16. Near the front of the upright on the top right hand side, fix a nail that extends 3/4" from the upright surface. Hang a thread with a needle at its end from this nail. Find the exact length of the point of suspension of the thread from the right face of the upright and from the back of the balance. In the base of the balance at a point exactly the same lengths from the upright and from the back of the balance fix a nail up through the base pointing upwards. The nail should extend about 1/2" above the base. When the needle hangs directly above this nail, the balance is level. This is done by turning the adjusting screws in the forward corners of the base.

17. The needle serving as the fulcrum should be long enough to extend somewhat past the front of the upright. Fix it such that the "eye" of the needle points to the front of the balance. Stick a pin through the needle eye and fix a broomstick to it. See that the needle is positioned such that the stick is exactly perpendicular to the arms of the common balance.

18. Fix a scale of the front of the upright near the broomstick point.

To insure proper balance

After suspending the weight pans from the balance arms and putting a scale at the base of the upright, you must see that the arms are of equal length. Temporarily balance the apparatus by addition of some weights to the lighter side. After temporarily balancing, put two exactly equal masses in each pan. If the pointer remains at zero, then the arms are equal. If not, the lower arm is too long and you can either (1) screw the longer arm further into the fulcrum block or (2) screw the shorter one out slighty. Then repeat the procedure with equal masses in each weight pan, untill the arms are equal. Then you can permanently balance it with empty weight pans by either (1) cutting some material from the heavier weight pan or (2) removing some wire from the heavier wire pan holder. Finally, hang a 2" or 3" piece of wire from one arm. It will serve as a fine balancing adjustment

Questions for further study

1. Why should the fulcrum for the balance arm be above the centre of gravity?

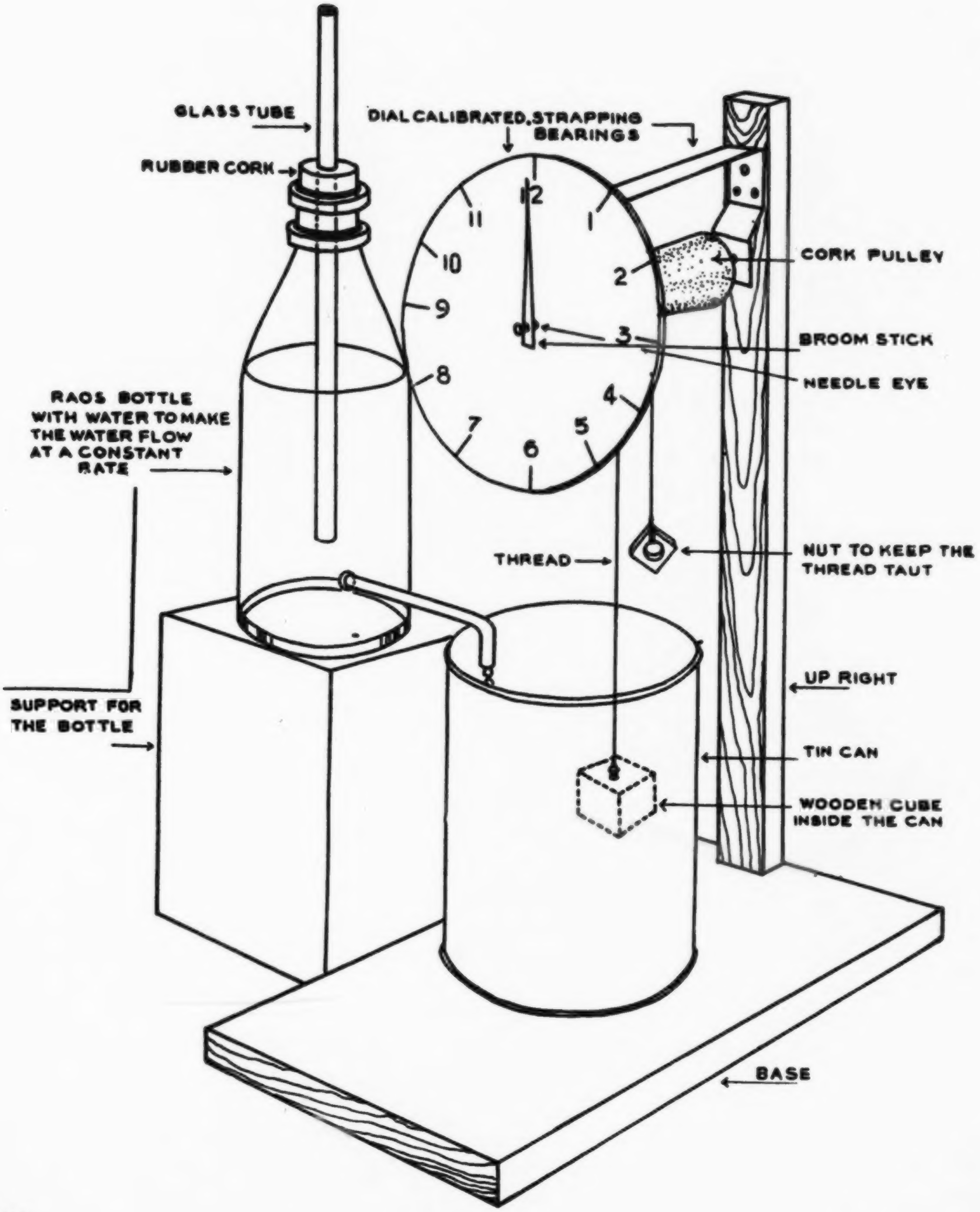
2. How can you make this balance more sensitive?

3. What function does the plumb line serve? If this was ignored when adjusting the balance, how would error be introduced?

4. What is the purpose of free swinging pans?

WATER TIMER

PERSPECTIVE VIEW


GLASS TUBE
RUBBER CORK
DIAL CALIBRATED, STRAPPING BEARINGS
12
1
2
3
4
5
6
7
8
9
10
11
CORK PULLEY
BROOM STICK
NEEDLE EYE
RAOS BOTTLE WITH WATER TO MAKE THE WATER FLOW AT A CONSTANT RATE
THREAD
NUT TO KEEP THE THREAD TAUT
UP RIGHT
SUPPORT FOR THE BOTTLE
TIN CAN
WOODEN CUBE INSIDE THE CAN
BASE

WATER TIMER

Materials required for construction

1. One small wooden cube.
2. One eye screw.
3. String.
4. Two small corks.
5. Cardboard.
6. 6" knitting needle.
7. 1/2" × 4" × 6" wooden base.
8. 1/2" × 1/2" × 24" wooden upright.
9. Strapping.
10. Tin, 3" diameter and 12" high.
11. Rao's bottle.

Procedure for construction

1. Cut and sand the base and upright and fix together as shown in the diagram.

2. Bend the piece of strapping in the shape of a "U". Punch holes 3/10" away from the ends. Fix it to the upright.

3. Glue the narrow ends of the corks together (sealing wax may be used).

4. Drive the knitting needle right through the centre of the faces of the two corks. This serves as the axle of the cork pulley. Fix this pulley in the strapping.

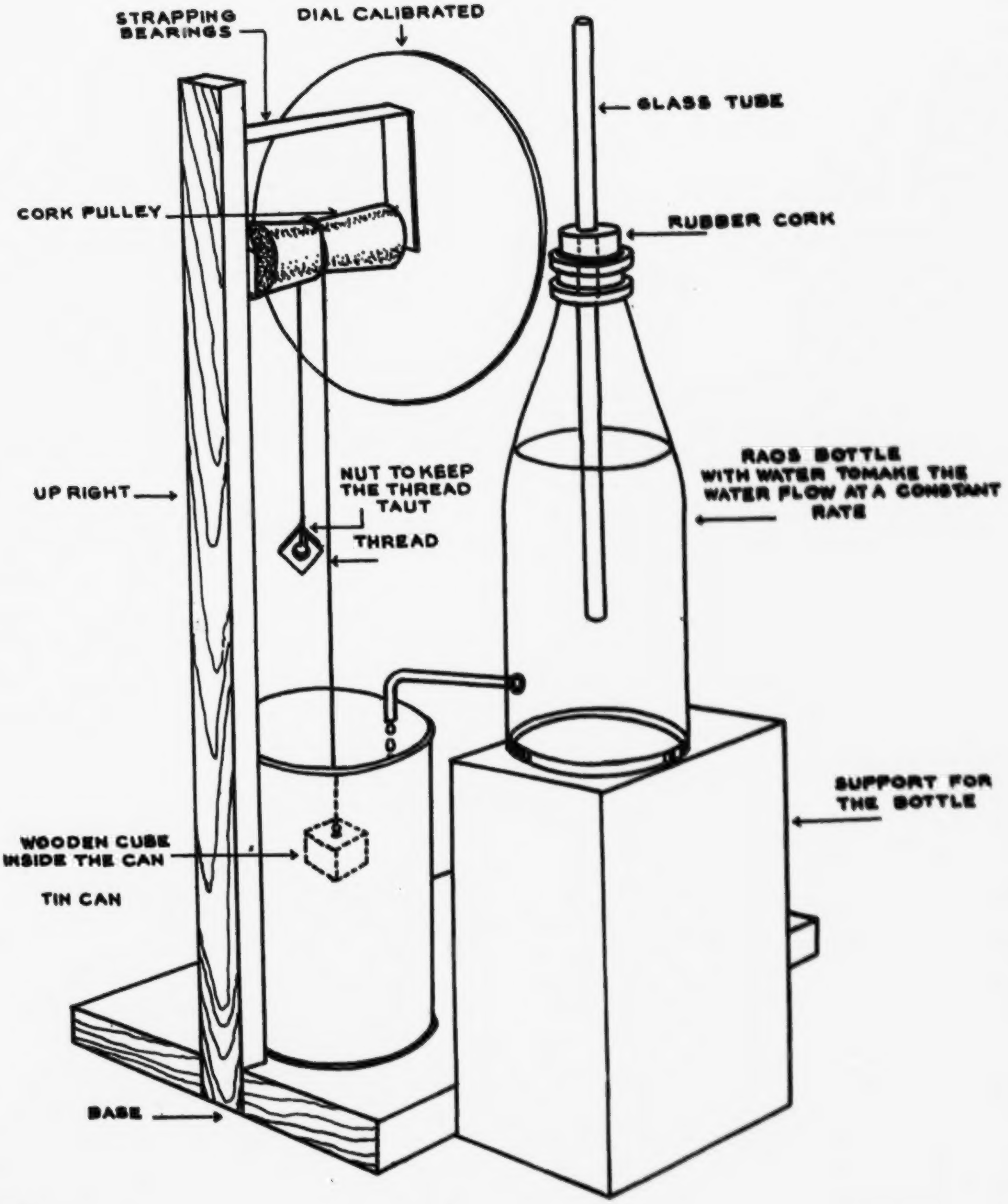
5. Put the screw eye into the wooden cube and tie the string to the screw eye. Tie a nut to the other end of the string to keep the string taut when it is passed over the pulley.

6. Put the tin can on the base close to the upright and put the wooden cube in it.

7. Arrange Rao's bottle in such a way

WATER TIMER

PERSPECTIVE VIEW


STRAPPING BEARINGS
DIAL CALIBRATED
GLASS TUBE
CORK PULLEY
RUBBER CORK
RAOS BOTTLE WITH WATER TOMAKE THE WATER FLOW AT A CONSTANT RATE
UP RIGHT
NUT TO KEEP THE THREAD TAUT
THREAD
SUPPORT FOR THE BOTTLE
WOODEN CUBE INSIDE THE CAN
TIN CAN
BASE

that the water from the bottle flows into the tin can.

8. Make a hole in the circular white cardboard and attach it to the strapping

9. Put a broomstick (a little less than the radius of the disk) in the eye of the knitting needle.

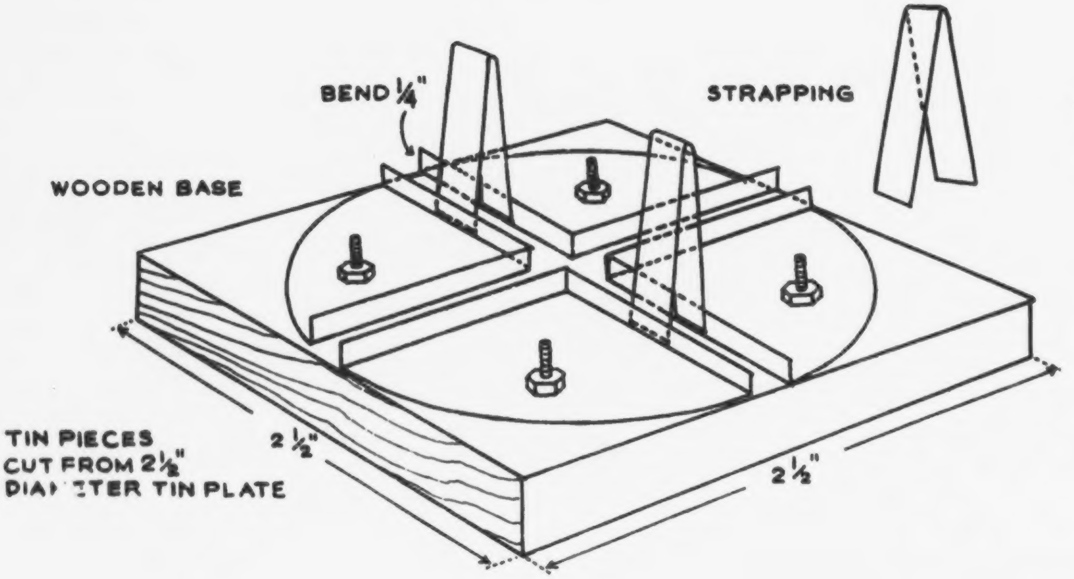
10. Mark the position of the broomstick as zero.

11. Release water from the bottle, and measure the time for the pointer to make a complete circle. Divide the circle into equal parts. For example, if the pointer takes 120 seconds to come to the zero mark again, then divide the disk into 120 equal divisions. Each division represents 1 second.

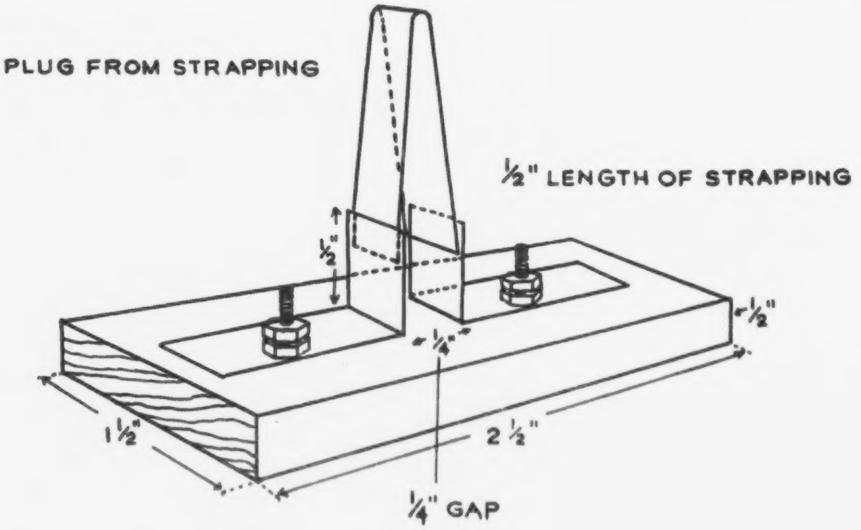
Uses in practicals and demonstrations

1. To measure accurately small intervals of time.
2. For use in simple pendulum experiments where a stop watch is needed and not available.

CURRENT REVERSER


BEND ¼"
STRAPPING
WOODEN BASE
TIN PIECES
CUT FROM 2½"
DIAMETER TIN PLATE
2½"
2½"

SWITCH


PLUG FROM STRAPPING
½" LENGTH OF STRAPPING
½"
½"
¼"
1½"
2½"
¼" GAP

CURRENT REVERSER

Materials required for construction

1. 1/2" × 2½" wood base.
2. One circular tin piece of 2½" diameter.
3. Four bolts and eight nuts.
4. 6" of strapping.

Procedure for construction

1. Cut, sand and varnish the wood base

2. Cut the circular tin piece into four sectors of equal size. This can be done by drawing two diameters at right angles to each other and cutting along them. Cut out 1/5" squares from the corners of the sectors. Bend the sides upwards (see diagram).

3. Arrange these pieces on the wood base with 1/4" gap between any two of them.

4. Mark the locations for fixing the bolts. Drill the holes in the tin pieces as well as in the wood block.

5. Bolt the tin pieces to the wood base.

6. Cut 3" pieces of strapping and bend each of them to a "V" shape.

7. Sand the surfaces of contact and assemble as shown.

PLUG TYPE SWITCH

Materials required for construction

1. 8" strapping.
2. Two bolts with four washers and four nuts.
3. 1/2" × 1½" × 2½" wood base.

Procedure for construction

1. Cut, sand and varnish the wood base.

2. Take two 2" pieces of strapping bend 1/2" part of each at right angles.

3. Drill two holes in the wooden base 1¾" apart.

4. Insert the bolts. Drill holes in the longer arm of the strapping 3/4" away from the end. Bolt the strapping pieces to the base. The gap between the perpendicular ends of the strapping should be 1/4". Fix the washers and the other nuts to each of the bolts.

5. The remaining 4" length of strapping is bent in a "V" shape.

6. Sand the contacting surfaces until the metal shines.

7. Place the "V" shaped piece in the gap between the base's strapping pieces.

LINEAR EXPANSION APPARATUS

Materials required for construction

1. 1/2" × 4" × 48" wood upright.
2. 1/2" × 4" × 6" wood base.
3. Two small glass tubes bent at right angles.
4. Iron rod about 1 meter long and 0.2" thick.
5. One worn-out tube light.
6. Broomstick.
7. One pin.
8. A small tin piece.
9. Meter scale.
10. Two corks.

Procedure for construction

1. Cut and sand the base upright and nail them together. Apply two coats of varnish.

2. Open both ends of the tube light, breaking the bakelite and breaking the glass seals.

3. Make two holes in each cork, one in the centre for the rod and the other for the glass tubing.

4. Close both ends of the tube light with the corks. Push the rod through the centre holes of the corks so that it is along the centre axis of the tube and protruding out of the corks at both ends.

5. Put the glass tubes in the other holes.

6. Place the tube light against the upright and secure in place with either strapping brackets or tape.

7. Put the broomstick on top of the rod approximately 2" from its end. Keep the broomstick in place and at

LINEAR EXPANSION APPARATUS

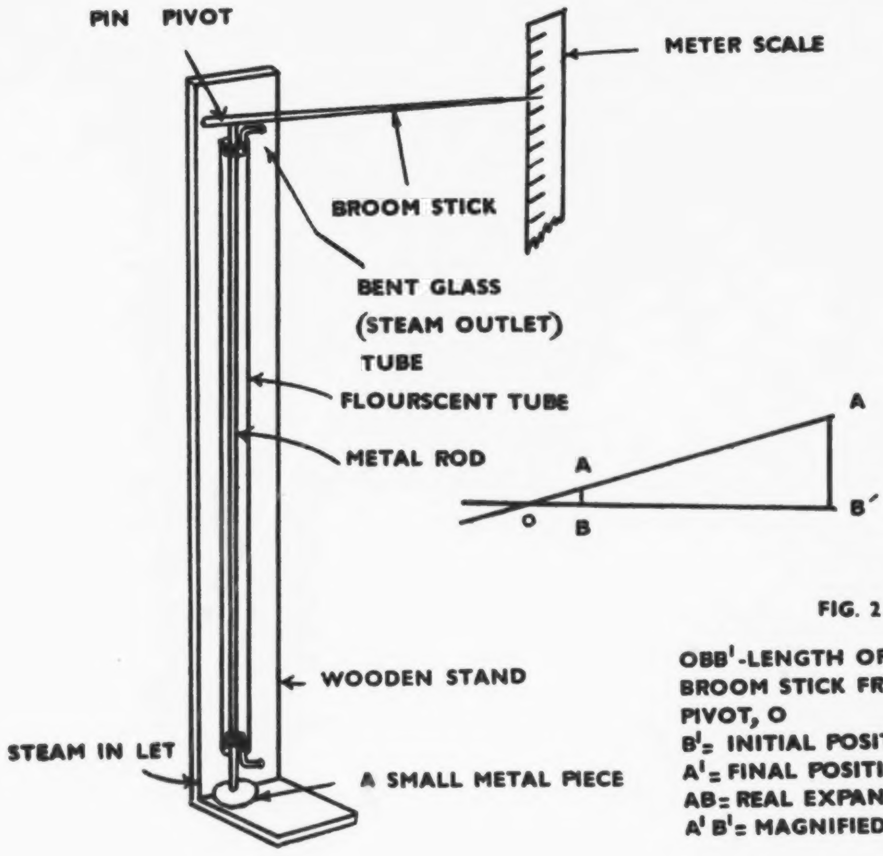

PIN PIVOT
METER SCALE
BROOM STICK
BENT GLASS (STEAM OUTLET) TUBE
FLOURSCENT TUBE
METAL ROD
WOODEN STAND
STEAM IN LET
A SMALL METAL PIECE
A
A
O
B
B´

FIG 1

FIG. 2

OBB'-LENGTH OF BROOM STICK FROM THE PIVOT, O
B'= INITIAL POSITION
A'= FINAL POSITION
AB= REAL EXPANSION
A'B'= MAGNIFIED EXPANSION

$$\alpha = \frac{OB.A'B'}{OB' \times L\,(T_2-T_1)}$$

the same time provide its pivot by sticking a pin through the broomstick and into the wooden upright.

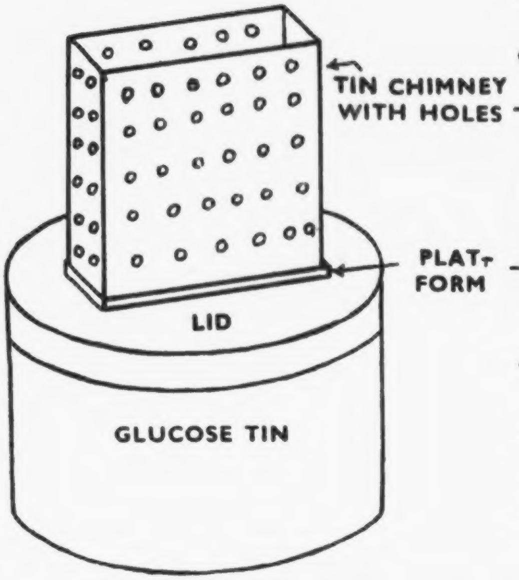
8. The meter scale is fixed vertically to a stand and is placed just behind the other end of the broomstick.

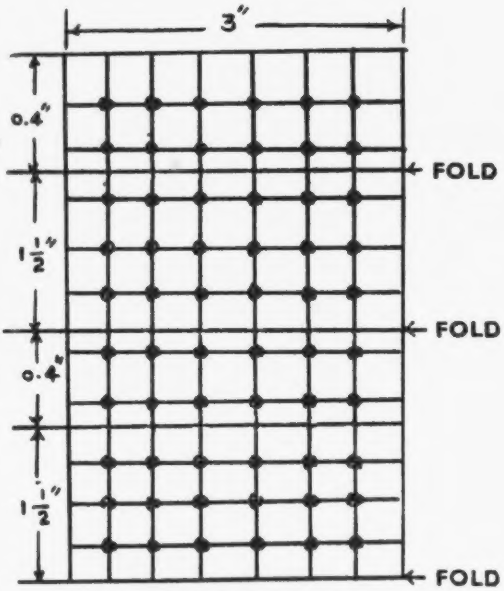
Questions for further study

1. Investigate the coefficient of linear expansion using rods of various metals.
2. How would you change the apparatus to find the coefficient of linear expansion of a wire ?

HEATING SOURCE

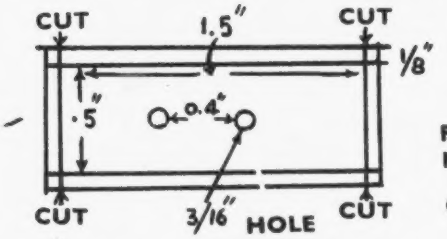
BLUE FLAME KEROSINE BURNER


TIN CHIMNEY
WITH HOLES
PLAT-
FORM
LID
GLUCOSE TIN

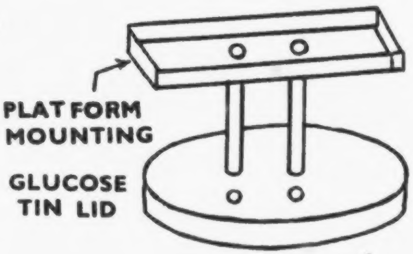

3"
0.4"
1½"
0.4"
1½"
FOLD
FOLD
FOLD

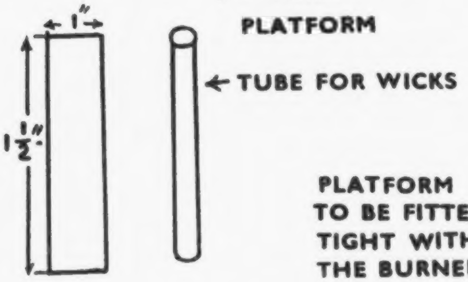
PLAN FOR THE CHIMNEY
FROM A TIN CAN

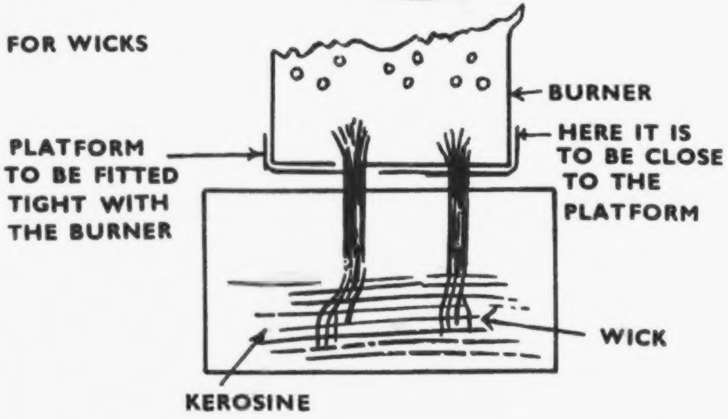
WE CAN GET CYLINDRICAL CHIMNEY WITH HOLES, FROM THE JANATA STOVE THIS CAN BE CONVERTED 1:1 TO THE RECTANGULAR ONE


CUT
1.5"
CUT
1/8"
.5"
0.4"
CUT
3/16" HOLE
CUT

PLATFORM


PLATFORM
MOUNTING
GLUCOSE
TIN LID


1"
1½"
TUBE FOR WICKS


BURNER
HERE IT IS
TO BE CLOSE
TO THE
PLATFORM
PLATFORM
TO BE FITTED
TIGHT WITH
THE BURNER
WICK
KEROSINE

BLUE FLAME KEROSENE BURNER

Materials required for construction

1. One glucose tin with lid 3″ diameter and 2½″ high
2. One 3″ × 4″ piece of tin.
3. One 1.7″ × 0.7″ piece of tin.
4. Two 0.5″ × 1.5″ pieces of tin.

Procedure for construction

1. *The chimney*: Mark the tin piece (see 2 above) into five parts—0.4″—1.5″—0.4″—1.5″–0.2″ as shown in the diagram.

2. Divide the surface of the tin piece into a squares of 0.3″. With a sharp 1/2″ nail punch holes at the intersection of the lines Then fold the tin piece into a cuboid of 1.5″ × 0.4″ × 3″. The extra 0.2″ part serves as a fold to hold the other free edge in position.

3. *Platform for the chimney*: Take the tin piece mentioned in 3 above, and mark a 1.5″ × 0.5″ rectangle on it. Cut off the corner squares and fold the edges to form a box. Punch two holes 0.4″ apart at bottom of the box.

4. *Wick holders*: Take tin pieces mentioned in 4 above and role them into tubes of 1.5″ length.

5. Punch two holes in the lid of the glucose tin which are 0.4″ apart. Align the holes of the platform with that of the lid and push the two wick holders through the holes (both the lid and platform). The holders should be just above the lid of the glucose can.

6. Prepare wicks from cotton thread and push them into the holders.

7. Fix the chimney to the platform.

8. A tin jacket around the chimney may be made to protect the flame from wind currents.

9. If the burner is working properly, there should be a smokeless blue flame hot enough to bend glass easily.

Uses in practicals and demonstrations

This piece of apparatus can be used as a cheap replacement for your spirit lamps. The cost of running it is much less and the heat produced is significantly greater.

Notes on use and construction

It is important that you punch the holes exactly as indicated in the instructions. This is very crucial to its operation. If a blue flame doesn't come, check your work against the instructions very carefully and make the necessary corrections. The jacket with holes can also be made from the cylindrical jacket of an old Janata stove.

GAS TANK FOR BUNSEN BURNER

Materials required for construction

1. Two 3/4" × 3/4" × 9" wood frame pieces.
2. Two 3/4" × 3/4" × 7½" wood frame pieces.
3. Two 3/4" × 3/4" × 6½" wood pieces.
4. Four 3/4" × 3/4" × 26" wood uprights.
5. One "Deccan Sweet" tin.
6. One kerosene tin 12½" × 6½" × 6½"
7. Two turpentine tins 3 litre capacity.
8. Sixteen pieces of 14 gauge wire each 3½" long.
9. 177" of polyethylene tubing 1/4" exterior diameter.
10. Two two-holed stoppers.
11. 32" of glass tubing.

Procedure for construction

1. Remove the tops of the two larger tins and smooth the sharp edges.

2. Make the square base frame from the two 3/4" × 3/4" × 9" pieces and the two 3/4" × 3/4" × 7½" pieces as shown in the diagram.

3. Drill eight small holes in a straight line halfway through the four 3/4" × 3/4" × 26" uprights starting 4" from one end and keeping a 2" space between each hole.

4. Bend the 14 gauge wire pieces in the shape shown in the diagram and fix them in each pair of holes starting from one end. Be sure that they do not protrude more than 1/2" from the uprights as shown in the diagram.

5. Nail the four uprights to the wooden base in the position shown.

6. Fit the whole frame inside the kerosene tin. Bolt the uprights to the top of the tin making sure that they are perpendicular to the base.

7. Drill two 1/4" holes on opposite sides of the "Deccan Sweet" tin 1" from the top.

8. Drill a 1/4" hole into the middle of the 6½" piece of wood.

9. Take two pieces of polyethylene tubing 45" in length and put them through the holes in the "Deccan Sweet" tin. Then put the tubing through the holes in the 6½" pieces of wood. Wedge one of these pieces 1" from the bottom of the "Deccan Sweet" tin and the other 1" from the top.

10. Attach the tubing that is in the piece of wood 1" from the top of the tin to a pump and the other to the first turpentine thin (gasoline tank) as shown in the diagram. Invert the "Deccan Sweet" tin and place inside the kerosene tin.

11. The gasoline tank should have a two-holed stopper. One long glass tube reaching to the bottom of this tank is inserted through this stopper. Another short glass tube is inserted so that it penetrates the can to a depth of only 1". The polyethylene tubing from the "Deccan Sweet" tin should be connected to the long glass tube in the gasoline tank.

12 The second turpentine can, the safety tank, should also have a two holed stopper with the same type of glass tubing in it. A 17" piece of polyethylene tubing is connected from the short tube in the gasoline tank to the long glass tube in the safety tank.

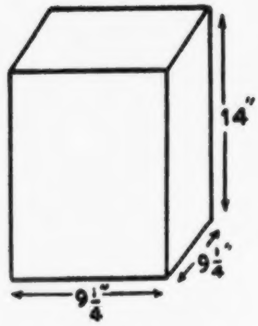
13. Polyethylene tubing, 70" in length, is connected from the short tube of the safety tank to the bunsen burner.

14. Fill the kerosene tin with water to 4/5ths of its capacity. Place a 3 litre tin full of water on top of the "Deccan Sweet" tin to serve as a weight.

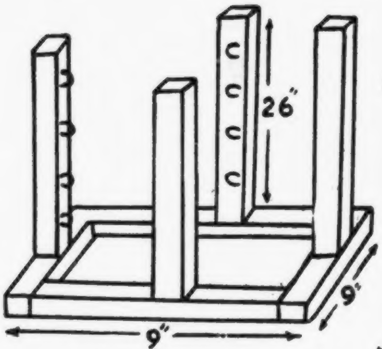
15. Fill the gasoline tank with a maximum of two litres of petrol.

16. The safety tank should be filled with water to 4/5ths of its capacity. This tank is a safety measure to prevent any back-fire from the bunsen burner.

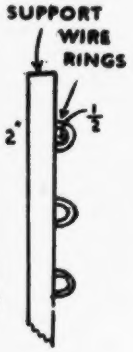
PARTS FOR GAS TANK AND BUNSEN BURNER

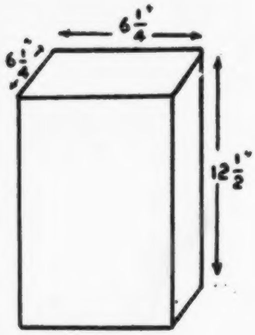


KEROSINE TIN

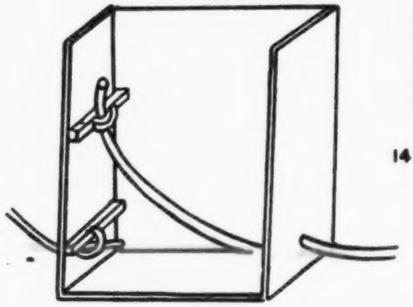


WOODEN SUPPORT FOR AIR RESERVOIR

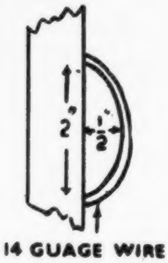

SUPPORT
WIRE
RINGS
2"
1/2

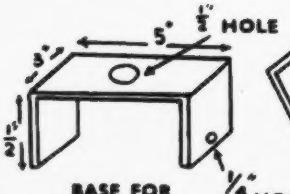

6 1/4"
6 1/4"
12 1/2"

OIL TIN

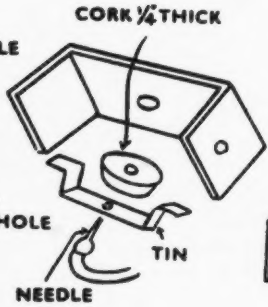


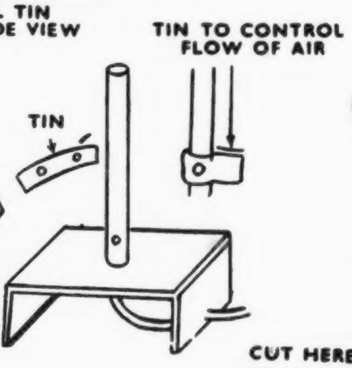
OIL TIN
INSIDE VIEW

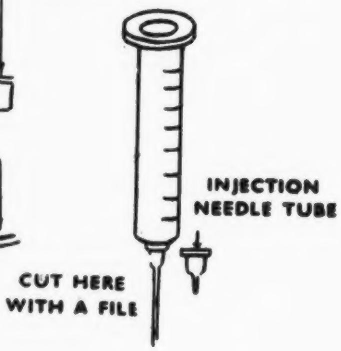

2"
1/2"
14 GUAGE WIRE


5"
1/2" HOLE
3"
2 1/2"
1/4" HOLE

BASE FOR BUNSEN BURNER


CORK 1/4 THICK
TIN
NEEDLE


TIN TO CONTROL FLOW OF AIR
TIN


INJECTION NEEDLE TUBE
CUT HERE WITH A FILE

17. **Pump** air into the "Deccan Sweet" tin to its capacity.

18. Check to make sure that there are no leaks in the connections and then light your Bunsen burner.

Uses in practicals and demonstrations

To provide an inexpensive and efficient heat source for student use.

Notes on use and construction

The Bunsen burner and the gas plant have the capacity of working for fifteen minutes with one pumping.

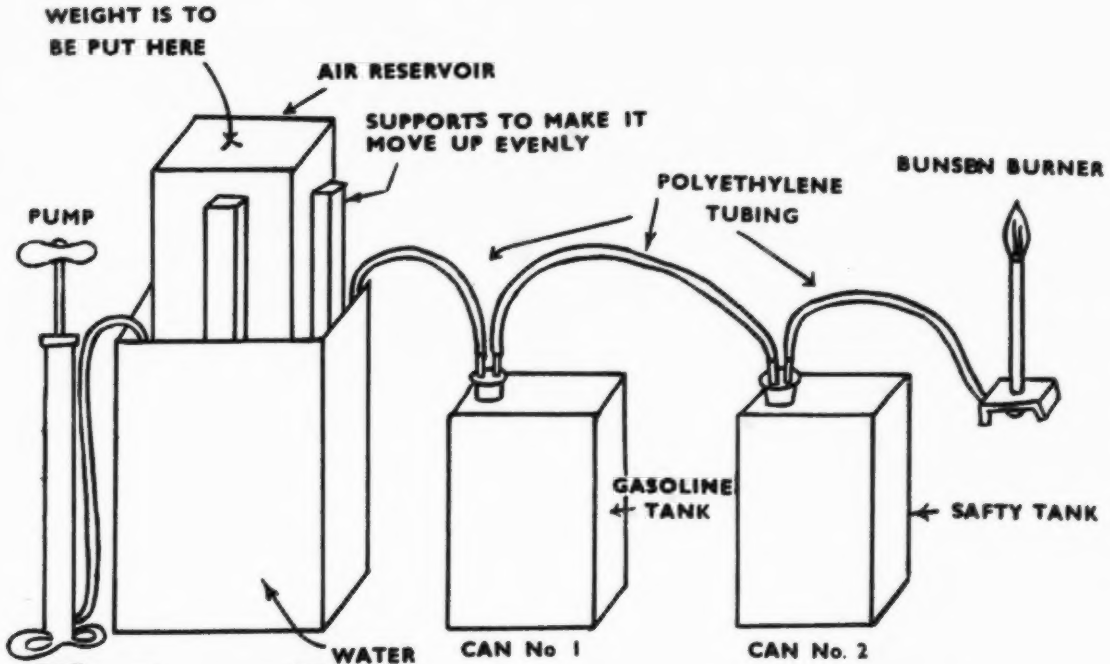
If injection needles are hard to find, then a ball point pen cartridge may be used. Simply use a small file and remove the ball from the point. But try to keep the hole small and if necessary place a piece of 32 gauge wire in the hole to slow down the flow of gas. Cut the cartridge to about 1" length and fit tightly in the copper tubing.

Another alternative to the injection needle would be to use a jet tube made from glass tubing.

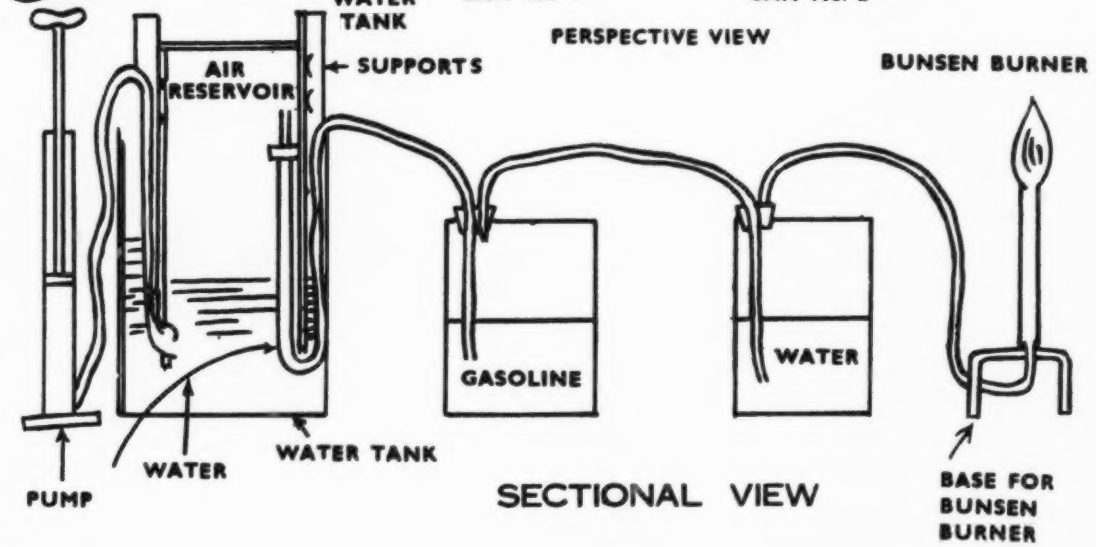
Notes on how it works

By forcing air through the fuel tank, petrol is vaporized, passed through a safety tank and finally to the Bunsen burner. The safety tank serves as a device to stop any back–fire through the polyethylene tubing before it reaches the fuel tank. This precaution must be observed. Before operating, check and make sure that the tubing coming from the fuel tank is well beneath the surface of the water in the safety tank.

GAS TANK AND BUNSEN BURNER


WEIGHT IS TO BE PUT HERE
AIR RESERVOIR
SUPPORTS TO MAKE IT MOVE UP EVENLY
POLYETHYLENE TUBING
BUNSEN BURNER
PUMP
GASOLINE TANK
SAFTY TANK
WATER TANK
CAN No 1
CAN No. 2

PERSPECTIVE VIEW


AIR RESERVOIR
SUPPORTS
BUNSEN BURNER
GASOLINE
WATER
PUMP
WATER
WATER TANK
BASE FOR BUNSEN BURNER

SECTIONAL VIEW

BUNSEN BURNER

Materials required for construction

1. 5½" of copper tubing 5/16" in diameter.
2. Injection needle.
3. 3/4" × 3" × 5" wood piece.
4. Two 3/4" × 3" × 2½" wood pieces.

Procedure for construction

1. Drill a 1/2" diameter hole in the centre of the 3/4" × 3" × 5" wood piece.

2. In one of the pieces mentioned in (2) above, drill a 1/4" hole 1/2" from the end at the middle of its 3" width as shown in the diagram.

3. Drill a 3/16" hole completely through the copper tubing 1" from one end.

4. Make a stand for the burner by attaching the 3/4" × 3" × 2½" pieces to the base piece as shown in the diagram.

5. Cut the cork to 1/4" thickness and drill a 1/4" hole in the centre.

6. Drill a 1/4" hole in the centre of a piece of strapping.

7. Attach the copper tubing to the 1/4" hole in the base making sure that 3/16" holes are just above the wood.

8. Break the end of an injection needle by cutting it with a small file. Insert the butt of the needle into the polyethylene tubing (from the safety tank); then put it in through the (1) strapping and the (2) cork. Pass the tubing through the hole in the platform and up into the copper tubing.

9. Nail the strapping and cork to the bottom of the platform. See diagram.

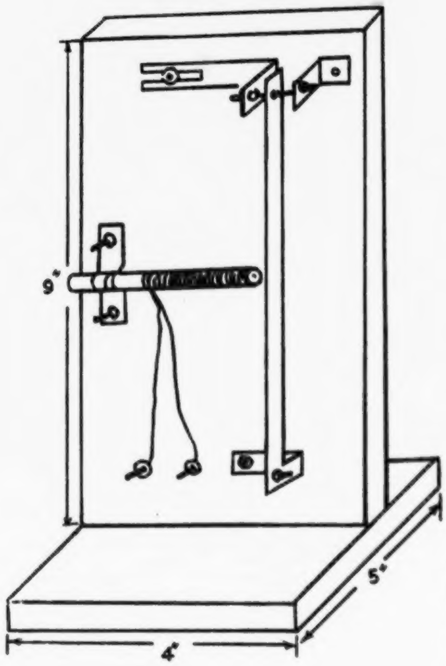
10. Have the tip of the needle come just up to the middle or bottom of the 3/16" holes in the copper tubing.

11. Cut two 3/16" holes in a piece of tin 1½" long and 5/16" wide such that they will be concentric with the holes in the copper tubing. Wrap the tin around the copper tube so that it fits fairly tightly. The air intake of the burner can be regulated by rotating this piece.

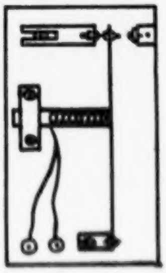
12. Take 10" of 32 gauge wire and roll it into a ball about 1/2" in diameter. Put the ball half way down the copper tube. This helps to make an even flame for your burner.

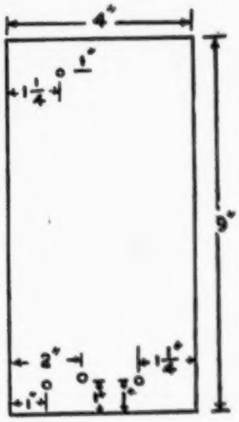
TELEGRAPH

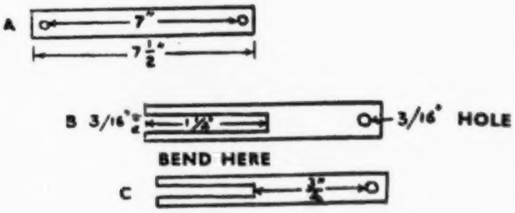
3 DIMENSIONAL VIEW

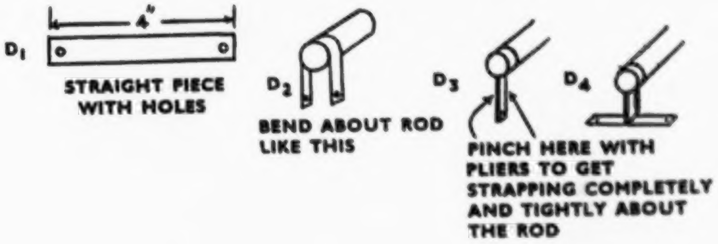


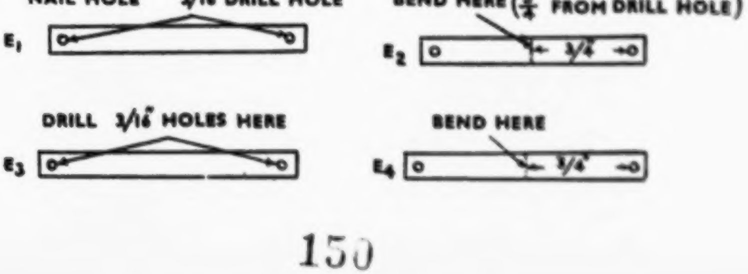
FLAT VIEW OF UPRIGHT FACE




4"
1"
1 1/4"
9"
2"
1 1/4"
1"


A
7"
7 1/2"
B 3/16"
1 1/2"
3/16" HOLE
BEND HERE
C
3/4"


4"
D1
STRAIGHT PIECE WITH HOLES
D2
BEND ABOUT ROD LIKE THIS
D3
PINCH HERE WITH PLIERS TO GET STRAPPING COMPLETELY AND TIGHTLY ABOUT THE ROD
D4


NAIL HOLE
3/16" DRILL HOLE
E1
BEND HERE (3/4" FROM DRILL HOLE)
E2
3/4"
DRILL 3/16" HOLES HERE
E3
BEND HERE
E4
3/4"

TELEGRAPH

Materials required for construction.

1. 1" × 4" × 9" wood piece.
2. 1" × 4" × 5" wood piece.
3. 3 metres of 24 gauge enamelled copper wire.
4. One soft iron rod 1 cm diameter and 2½" in length.
5. Metal strapping.
6. Ten 3/16" bolts with nuts.

Procedure for construction

1. Cut and sand the wood pieces given in 1 and 2 above.

2. Drill 3/16" holes in the upright as shown in the diagram.

3. Nail the upright to the centre of the base and varnish the pieces.

4. Cut five pieces of metal strapping to these exact lengths: one piece 7½", one piece 2½", two pieces 1¾" and one piece 4½".

5. In the 7½" piece, drill two 3/16" holes which are exactly 7" apart from centre to centre.

6. Drill a 3/16" hole in one end of the 2½" piece of strapping. At the other end cut a notch along the longitudinal axis of the strapping 1¼" long and 3/16" wide. At a point exactly 1¾" from the centre of the hole, bend the strapping up 90°.

7. Drill a 3/16" hole in each end of the 4½ piece of strapping. Bend this piece of strapping around the iron rod which you will use for the core of the electromagnet and pinch the strapping at the point where the bends meet. Thus the strapping should conform exactly to the shape of the rod and the ends of the strapping should meet and be pressed together with the end holes lined up. Bend the feet on this piece such that the center of the iron rod will be 3/4" above the upright.

8. Drill a 3/16" hole near either end of one of the 1¾" pieces. Make a nail hole 1/2" from the other end. Bend the piece making a 90° angle 3/4" from the center of the 3/16" hole.

9. In the other 1¾" piece, drill a 3/16" hole in each end. Make the 90° angle 3/4" from one of these holes.

10. Place the 4½" strapping piece holding the iron rod at the left hand side of the upright as shown in the drawing. Bolt the piece to the upright.

11. Fasten the 2½" piece in the hole at the upper left hand part of the upright as shown in the diagram. When the bolt is loose, the strapping should slide freely along the slot.

12. Nail 1¾" piece (the one with the nail hole) at the upper right hand corner of the upright. See diagram. This piece should be on a straight line with the piece on the top life. This piece is used for providing a rest for the moving piece of the telegraph.

13. Bolt the other 1¾" piece to the hole on the right bottom side of the upright. Bolt the shorter arm of this piece.

14. With a 3/8" long 3/16" bolt, fasten the 7½" piece of strapping as shown in the diagram. Put a 1/4" to 3/8" long 3/16" bolt through the hole at the other end and fasten with a nut. This will serve as the "hammer" of the moving piece.

15. Leaving about 5" free, wind all the copper wire around the iron rod neatly. Note: Leave about 1" of one end of the rod free from the windings so that this end may be used in the metal strapping holder.

16. Remove the enamel insulation from the ends of the wire and attach them to the contact bolts at the bottom of the upright.

17. Connect one or at most two cells to the terminals and with a little adjusting your telegraph should work.

Uses in practicals and demonstrations

This piece of apparatus is useful in teaching an application of electromagnetism.

Notes on use and construction

It is most important that when constructing this piece of apparatus that the plans be followed precisely. Adjustment of the distance between the moveable arm and the electromagnet will be necessary after you have completed assembling this piece. This may take some time and patience.

ADJUSTABLE RING STAND

Materials required for construction

1. 1/2" × 1/2" × 12" (or ½" diameter dowel) wooden upright.
2. 1/2" × 4" × 6" wood base.
3. 19" of strapping.
4. 2" of stiff wire.

Procedure for construction

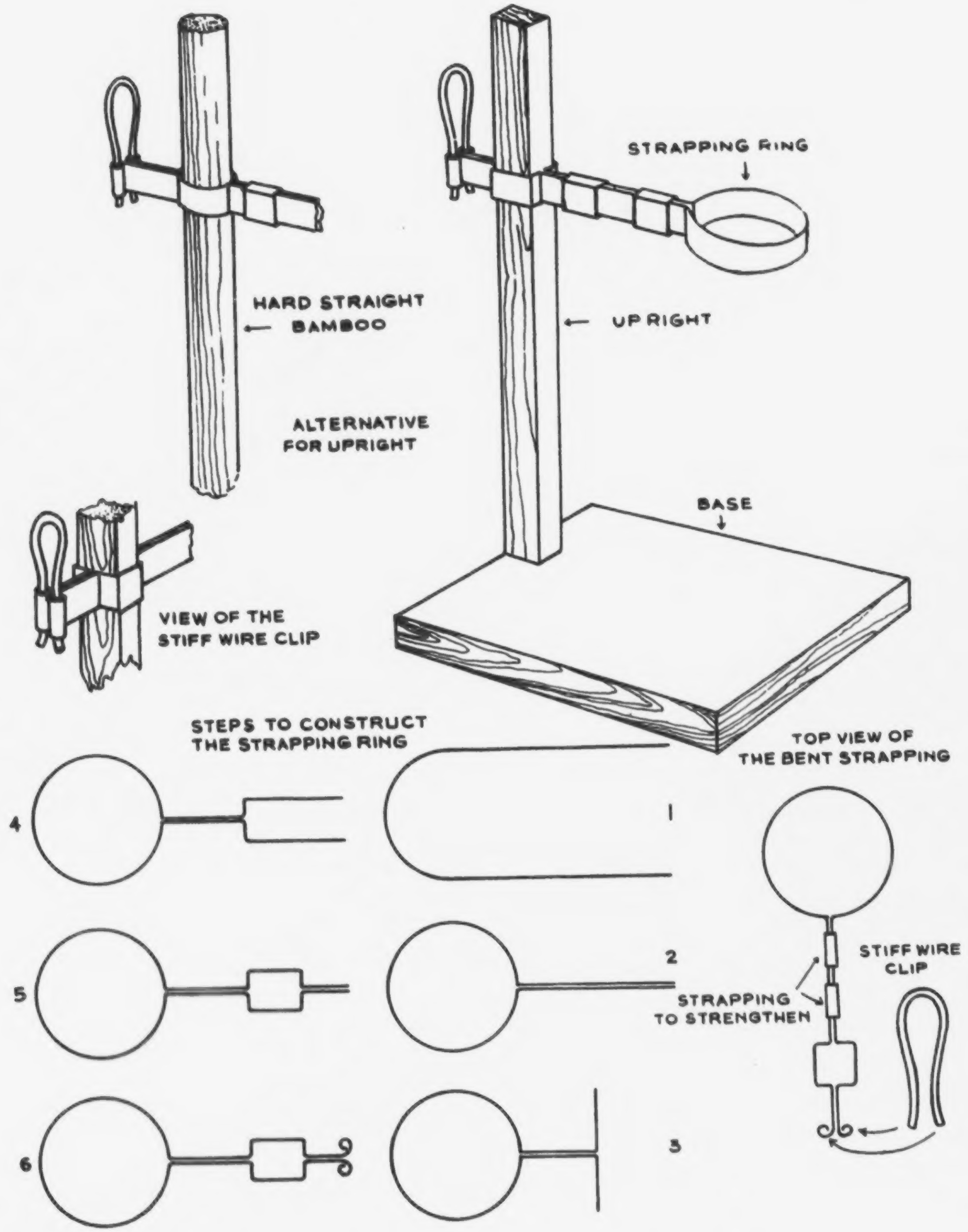
1. Cut and sand the upright and base.

2. Cut a notch on the 4" side with the saw and chisel. The notch should conform to the dimensions of the upright and be located in the centre of one end. Nail the upright in this notch and varnish this assembly with two coats of varnish.

3. Bend the strapping so that a 2½" to 3" diameter ring is formed in the middle.

4. Take two 1½" pieces of strapping and bend them around the strapping arm between the ring and the upright.

HEATING STAND OR FUNNEL STAND



STRAPPING RING
HARD STRAIGHT BAMBOO
UPRIGHT
ALTERNATIVE FOR UPRIGHT
BASE
VIEW OF THE STIFF WIRE CLIP
STEPS TO CONSTRUCT THE STRAPPING RING
TOP VIEW OF THE BENT STRAPPING
1
2
3
4
5
6
STIFF WIRE CLIP
STRAPPING TO STRENGTHEN

5. 2" from the ring, bend the arms of the ring to form a square which will conform to the shape of the upright. See diagram.

6. Bend the ends of the strapping forming two cylindrical loops as shown in the diagram.

7. Bend the stiff wire into a "U" shape with the ends of the "U" being fairly close to each other.

8. Fix the ring to the upright and insert "U" shaped holder into the ends. The pressure exerted should be enough to fix in place.

LIGHT BULB TEST TUBE OR FLASK

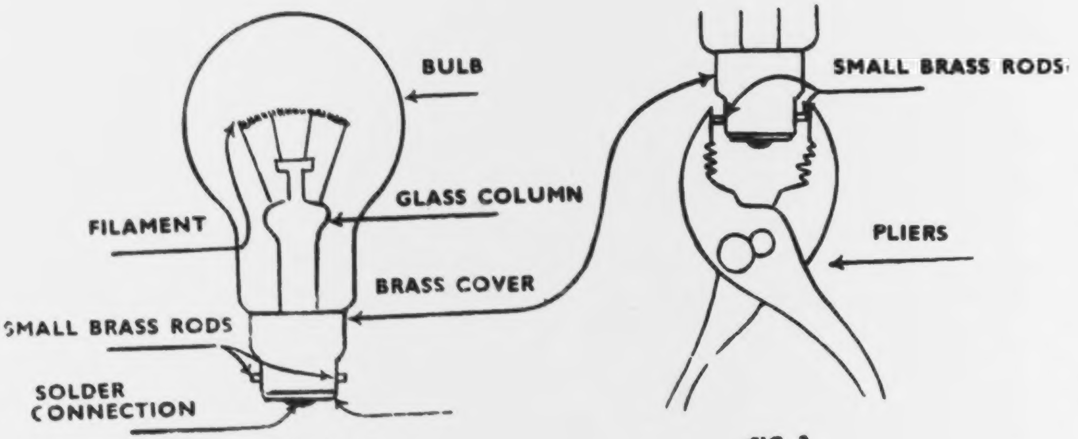

BULB
GLASS COLUMN
FILAMENT
BRASS COVER
SMALL BRASS RODS
SOLDER CONNECTION
SMALL BRASS RODS
PLIERS

FIG 1 FIG 2

LIGHT BULB TEST TUBE OR FLASK

Materials required for construction

1. Burned out light bulbs.
2. Sharp pointed instrument.

Procedure for construction

Caution

Hold the light bulb with a cloth at all stages. Wearing glasses is also recommended

Note

Empty light bulbs can be used as test tubes and flasks. They are made of pyrex glass and can withstand high temperatures.

1. Remove the two soldered connections at the base of the bulb by wedging under them with a pointed instrument. Lift them off, breaking the wires.

2. Next, break up the ceramic base by placing the pointed instrument in the wire holes uncovered in step 1, and twisting the instrument until the ceramic breaks up and falls out. This may take some patience.

3. Another way to initially crack the ceramic is to grip the small brass rods on the side of the brass cover with a pair of pliers and squeeze very hard.

4. When the ceramic base is removed you can see the inside of the hollow glass column which goes into the bulb. This must be broken off. Insert the screwdriver or the sharp end of the triangular file into the column and give it a sharp tap on the table top; the column will be broken off inside the bulb.

5. Using the screw driver or file, enlarge the hole in the glass enough so that the glass column can be removed. Continue to smooth out and enlarge the hole and remove most of the seating material.

6. Clean the bulb and it is ready for use.

WIRE TEST TUBE HOLDER

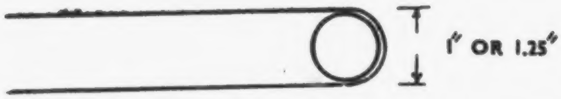


FIG. 1

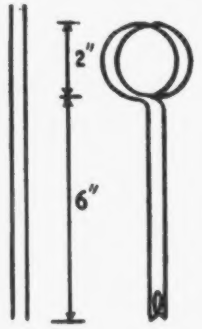


FIG. 2

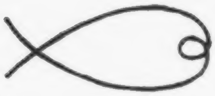


FIG. 3

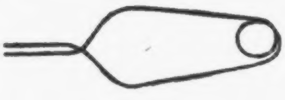


FIG. 4

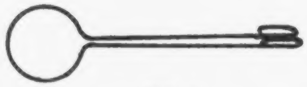
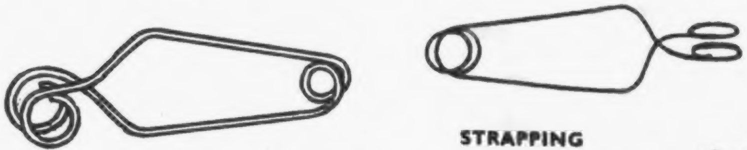
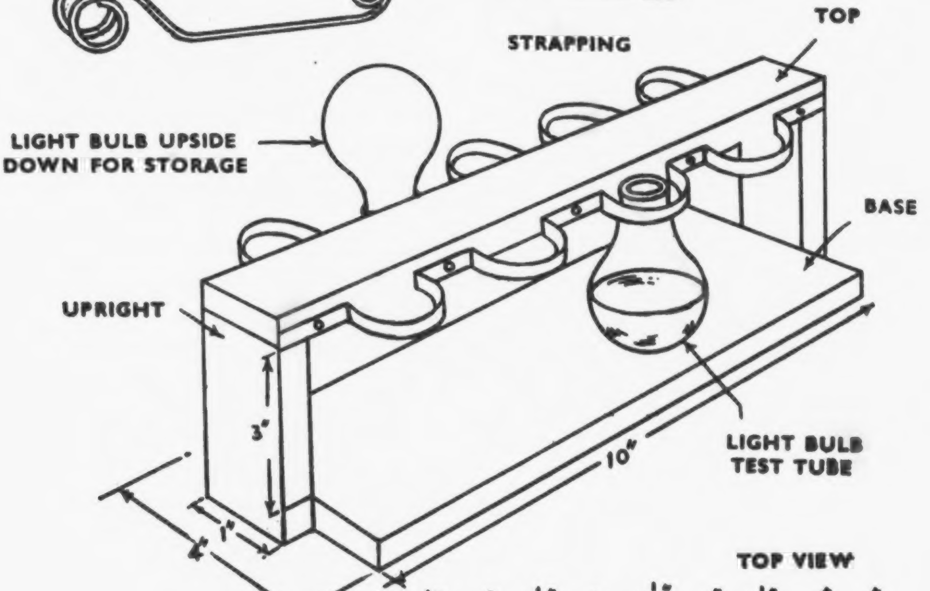


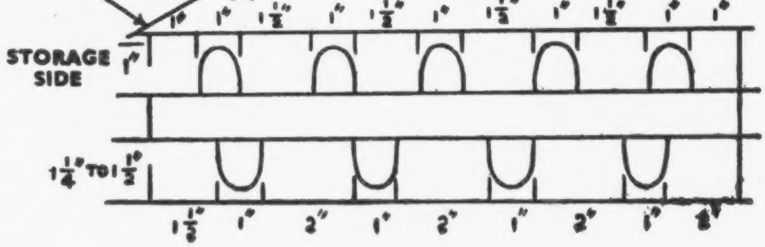
FIG. 5



STRAPPING


TOP
LIGHT BULB UPSIDE DOWN FOR STORAGE
BASE
UPRIGHT
3"
10"
LIGHT BULB TEST TUBE
1"
4"

TOP VIEW


1"
1"
1½"
1"
1½"
1"
1½"
1"
1½"
1"
1"
STORAGE SIDE
1"
1¼" TO 1½"
1½"
1"
2"
1"
2"
1"
2"
1"
2"

WIRE HOLDER FOR LIGHT BULB TEST TUBES

Materials required for construction

2½ to 3′ of strong wire.

Procedure for construction

1. Straighten the piece of wire. Place its ends together, and form a 1″ circle at its mid-point. This may be done by wrapping the wire around an object of a suitable diameter.

2. At points about 6″ from the circle, bend 2″ diameter circles in the wire.

3. Shape the handles until the holder looks like the one in the diagram.

LIGHT BULB TEST TUBE RACK

Materials required for construction

1. 1/2″ × 4″ × 12″ wood base.
2. 1/2″ × 1″ × approximately 13″ wood top piece (see note).
3. Two pieces 1/2″ × 1″ × approximately 3½″ uprights.
4. Three feet metal strapping.

Procedure for construction

Note: For most light bulbs the distance between the base and the top should be exactly 3″ as you will notice on the diagram. Therefore, the length of the uprights should be 3″ plus the thickness of the bottom piece. As the wood varies somewhat in thickness, it may not be exactly 1/2″. Measure the wood and cut the uprights to the proper lengths. The length of the top piece should be adjusted in the same way, its length being the length of the base plus the thickness of the uprights.

1. Cut and sand the wood pieces.

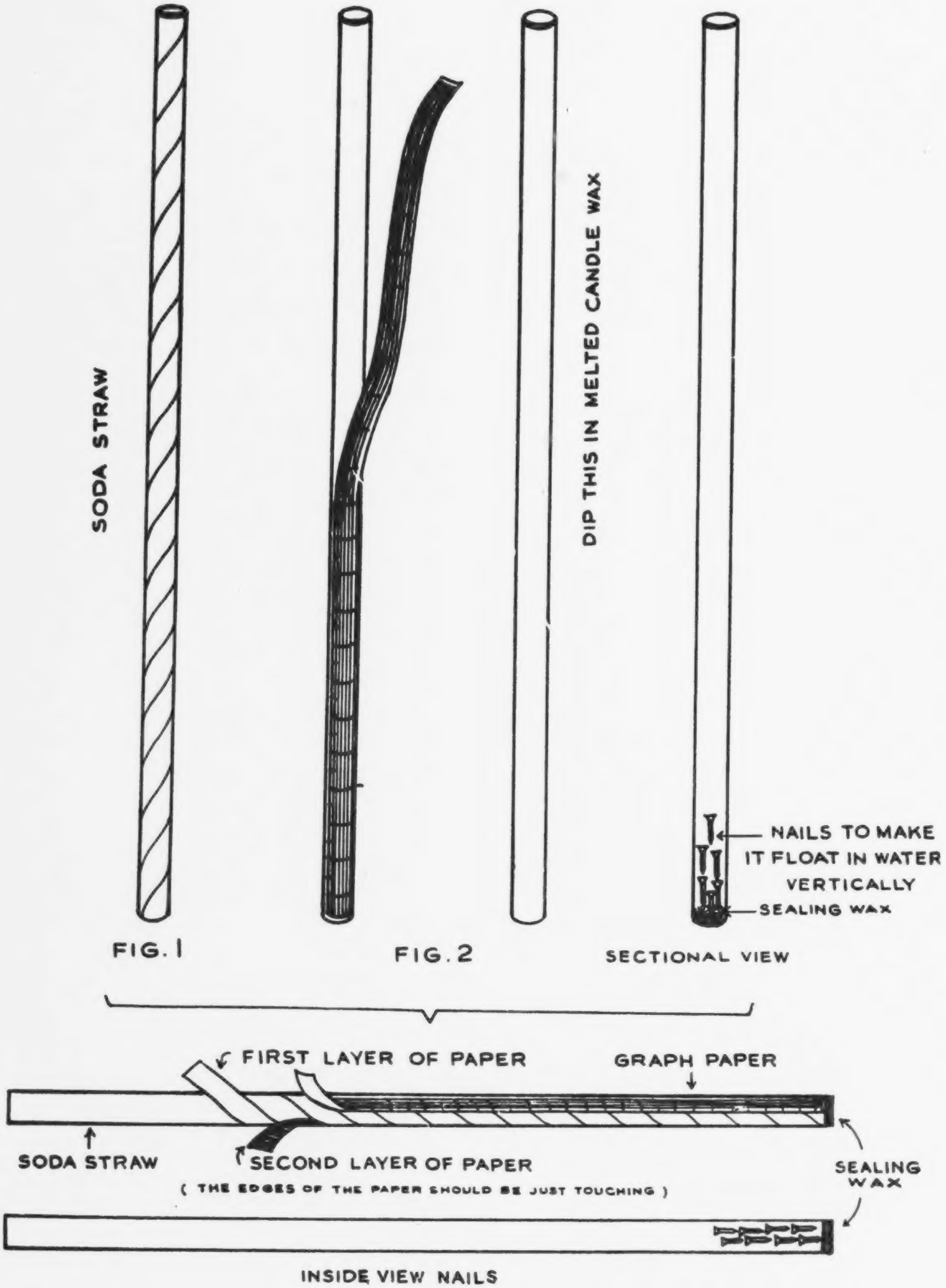
2. Nail the two uprights to the base. Nail the top pieces to the uprights.

3. Varnish the entire piece.

4. Bend the strapping to the shape indicated in the diagram.

5. Be certain that the light bulbs will fit into the loops. Then punch holes in the strapping for attachment to the top piece. The holes may be punched with large 3/4″ nails.

HYDRO METER


SODA STRAW
DIP THIS IN MELTED CANDLE WAX
NAILS TO MAKE IT FLOAT IN WATER VERTICALLY
SEALING WAX
FIG. 1
FIG. 2
SECTIONAL VIEW
FIRST LAYER OF PAPER
GRAPH PAPER
SODA STRAW
SECOND LAYER OF PAPER
(THE EDGES OF THE PAPER SHOULD BE JUST TOUCHING)
SEALING WAX
INSIDE VIEW NAILS

SIMPLE HYDROMETER

Materials required for construction

1. One soda straw.
2. Two pieces of strong wire.
3. Long 1/4" wide paper strips.
4. Candle wax or sealing wax.
5. Varnish.
6. Graph paper.
7. Flour paste.

Procedure for construction

1. Cut long and uniform 1/4" wide strips from regular white paper. Apply thick flour paste to the strip and wrap it spirally around the straw such that each turn of the paper is adjacent to but not on top of the preceding turn. Cover the straw twice in this manner. A narrow piece of graph paper should be cut and applied at this time. It should be numbered beginning with 0.0 at the bottom.

2. While the paste is drying, insert the wire pieces into one end of the straw and seal that end with wax.

3. When the paste is dry, give the hydrometer two coats of varnish.

4. Test the hydrometer. If it doesn't stand upright insert additional pieces of wire through the top and then seal with wax.

5. For a hydrometer of this type specific gravity of the liquid is equal to:

$$\frac{\text{scale reading in water}}{\text{scale reading in X}}$$

6. The dry stem of a maize plant or a wooden dowel of a uniform diameter can also be used to construct the hydrometer. To make the wood or maize float vertically, weight one of its ends.

Uses in practicals demonstrations

1. To illustrate the laws of flotation.
2. To determine the specific gravity of liquids.

Questions for further study

1. Does the hydrometer displace the same volume of any liquid in which it floats? What is the reason for your answer?

2. How can convert the hydrometer into a lactometer, alchoholmeter or a sulfuric acid meter?

3. Can you use any floating body to measure specific gravity ?

4. Why should the hydrometer float vertically only?

5. If the cross section of the hydrometer were a square, rectangle, hexagon or the like, would it be useful for finding the specific gravity of liquids?

6. Is the cross sectional area a relevent variable when considering the proper functioning of the hydrometer? What are the reasons for your answer?

7. How can you increase the sensitivity of the hydrometer?

TRI-POD STAND

Materials required for construction

54" of heavy wire

Procedure for construction

1. Cut the wire into three equal pieces of 18".

2. Take two pieces and twist them together for the first 7"

3. Take the third piece aud twist it in a similar manner but with the free ends of the first two pieces. See diagram.

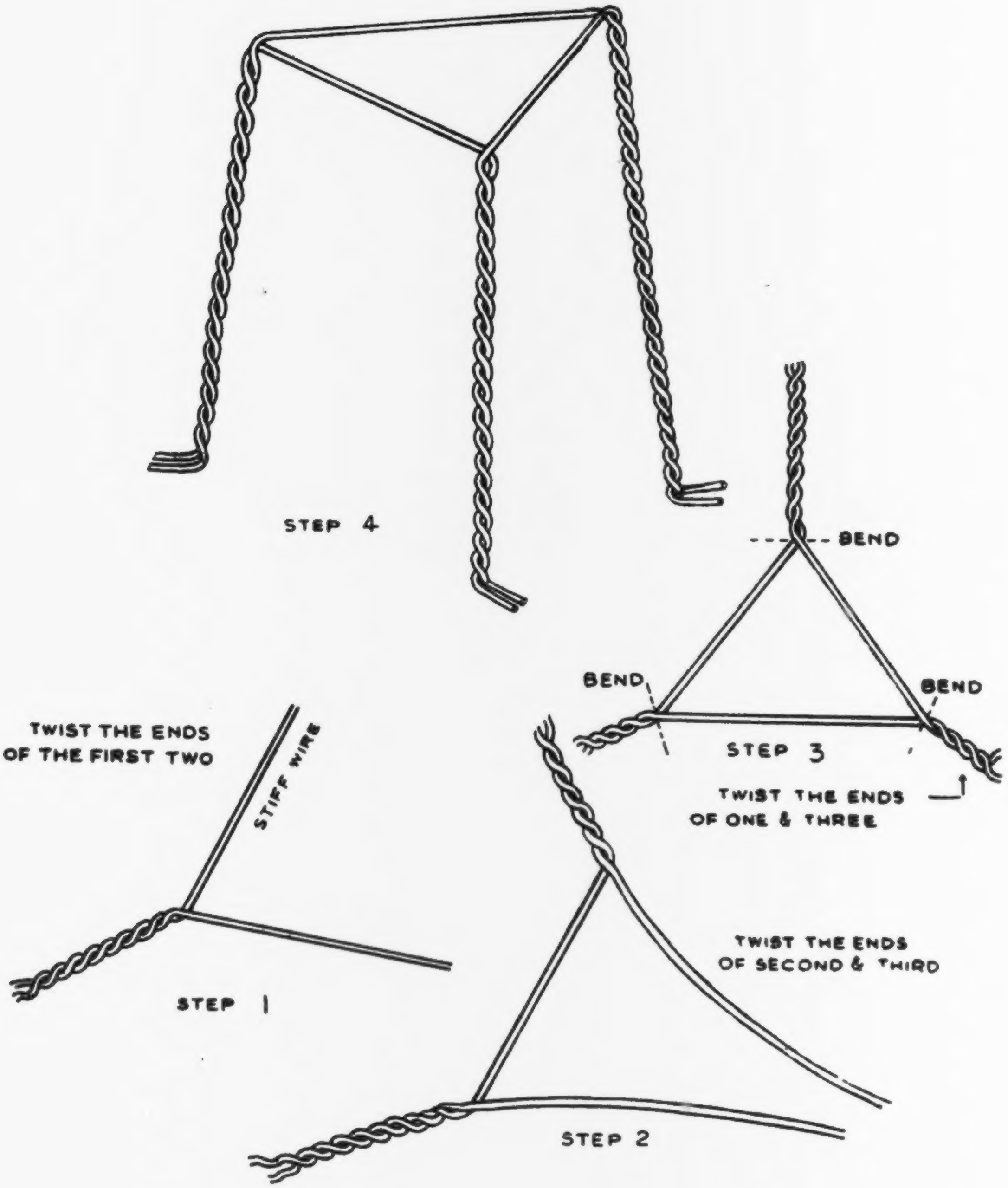
4. The twisted portions should all be 7" in length.

5. The triangle formed at the centre should have equal sides of 4" in length.

6. Bend the finished parts at the corners of the triangle to form the legs.

7. The last inch of each leg is to be bent outwards (away from the triangle) to form "feet" for further support.

TRIPOD STAND

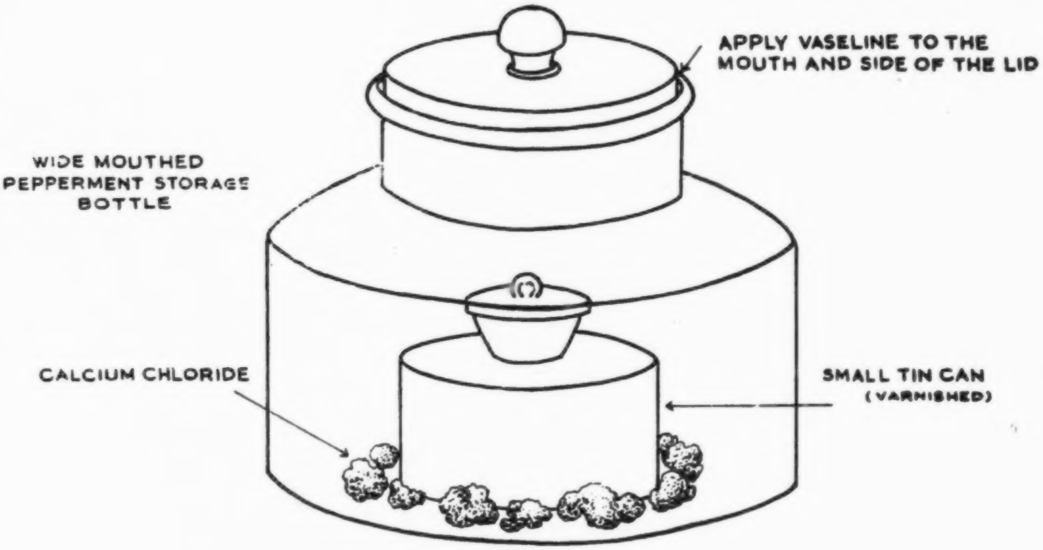

STEP 4
BEND
BEND
BEND
STEP 3
STIFF WIRE
STEP 1
STEP 2

TWIST THE ENDS OF ONE & THREE

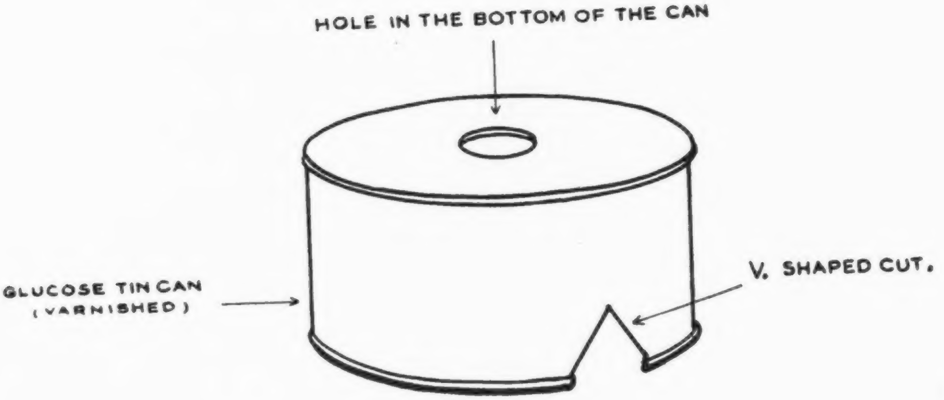
TWIST THE ENDS OF THE FIRST TWO

TWIST THE ENDS OF SECOND & THIRD

DESICCATOR


APPLY VASELINE TO THE MOUTH AND SIDE OF THE LID
WIDE MOUTHED PEPPERMENT STORAGE BOTTLE
CALCIUM CHLORIDE
SMALL TIN CAN (VARNISHED)

BEEHIVE SHELF


HOLE IN THE BOTTOM OF THE CAN
GLUCOSE TIN CAN (VARNISHED)
V. SHAPED CUT.

DESSICATOR

Materials required for construction

1. One peppermint bottle of 6" diameter.
2. Four 1" cubes of wood.
3. One tin small enough to fit through the mouth of the bottle.

Procedure for construction

1. Apply vaseline to the mouth and side of the lid of the peppermint bottle.
2. Varnish the small tin.
3. Assemble as shown in the diagram.

BEEHIVE SHELF

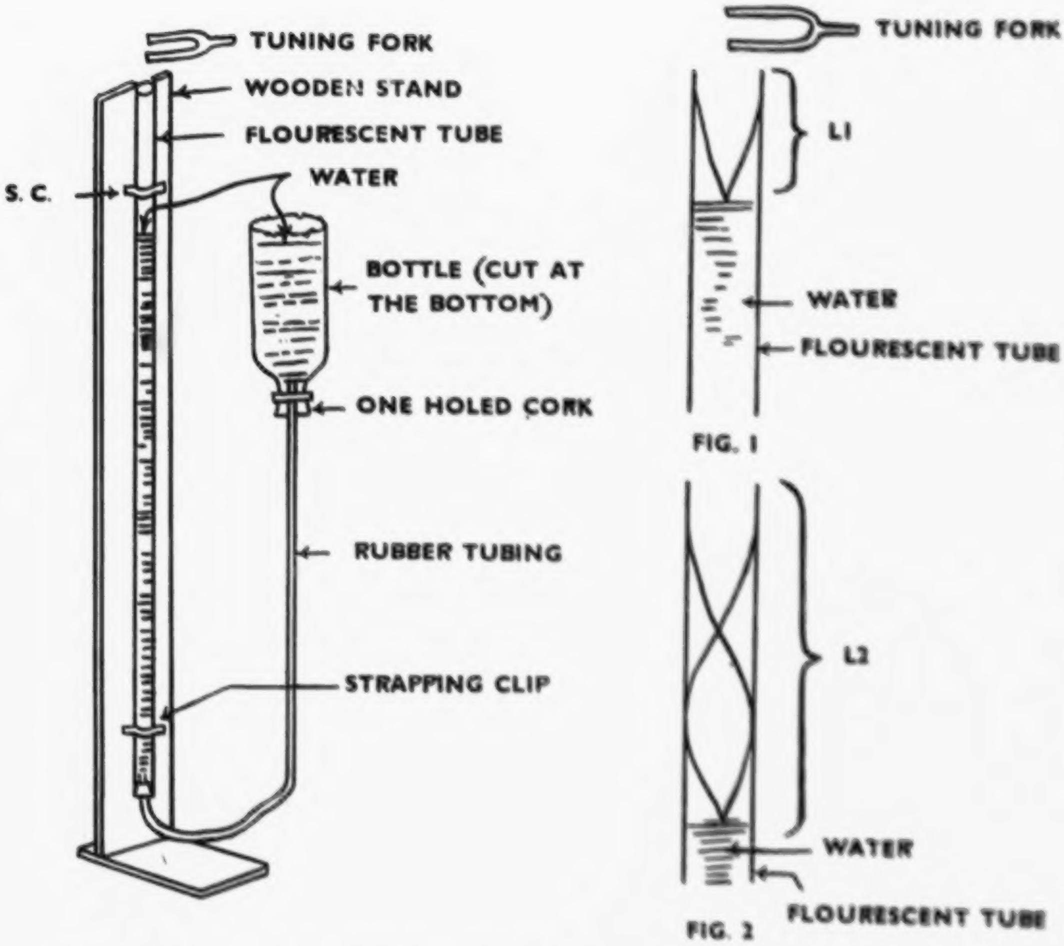
Materials required for construction

One small glucose tin.

Procedure for construction

1. Cut a "V" shaped notch 1/2" high on the side at the top of the can.
2. Invert the can and drill a hole 3/8" to 1/2" in diameter in the bottom.
3. Varnish the tin.

UELOCITY OF SOUND APPARATUS


TUNING FORK
WOODEN STAND
FLOURESCENT TUBE
S. C.
WATER
BOTTLE (CUT AT THE BOTTOM)
ONE HOLED CORK
RUBBER TUBING
STRAPPING CLIP
TUNING FORK
L1
WATER
FLOURESCENT TUBE
FIG. 1
L2
WATER
FLOURESCENT TUBE
FIG. 2

VELOCITY OF SOUND APPARATUS

Materials required for construction

1. One tube light.
2. One 4 pound bottle.
3. Two one-holed rubber stoppers.
4. 1/2" × 4" × 50" wooden upright.
5. 1/2" × 4" × 12" wooden base.
6. Rubber tubing.
7. Glass tubing.

Procedure for construction

1. Cut the base and upright to size. Attach them as shown in the diagam. Varnish.

2. Open both ends of the flourescent tube (tube light) leaving the metal end pieces on, if possible. Wash the tube light by washing with water and a rag.

3. Secure the tube to the upright by using metal strapping brackets as shown in the diagram.

4. Put the one-holed stopper in the bottom of the tube and fix a small glass tube in the hole. Attach the rubber tubing.

5. Cut-off the bottom of the 4 pound bottle (see Chapter VII). Place the other one-holed stopper in its mouth.

6. Insert another glass tube in the bottle's stopper and attach the other end of the rubber tubing.

Uses in practicals and demonstrations

1. To find the velocity of sound.
2. To find the wavelengths of sound waves.
3. To demonstrate resonance.

Questions for further study

1. What is the relationship between the wavelengths of two sounds one octave apart?

2. Does the distance between the tuning fork and the top of the cylinder make any difference in the results?

3. Does the diameter of the tube affect the results? Does its length?

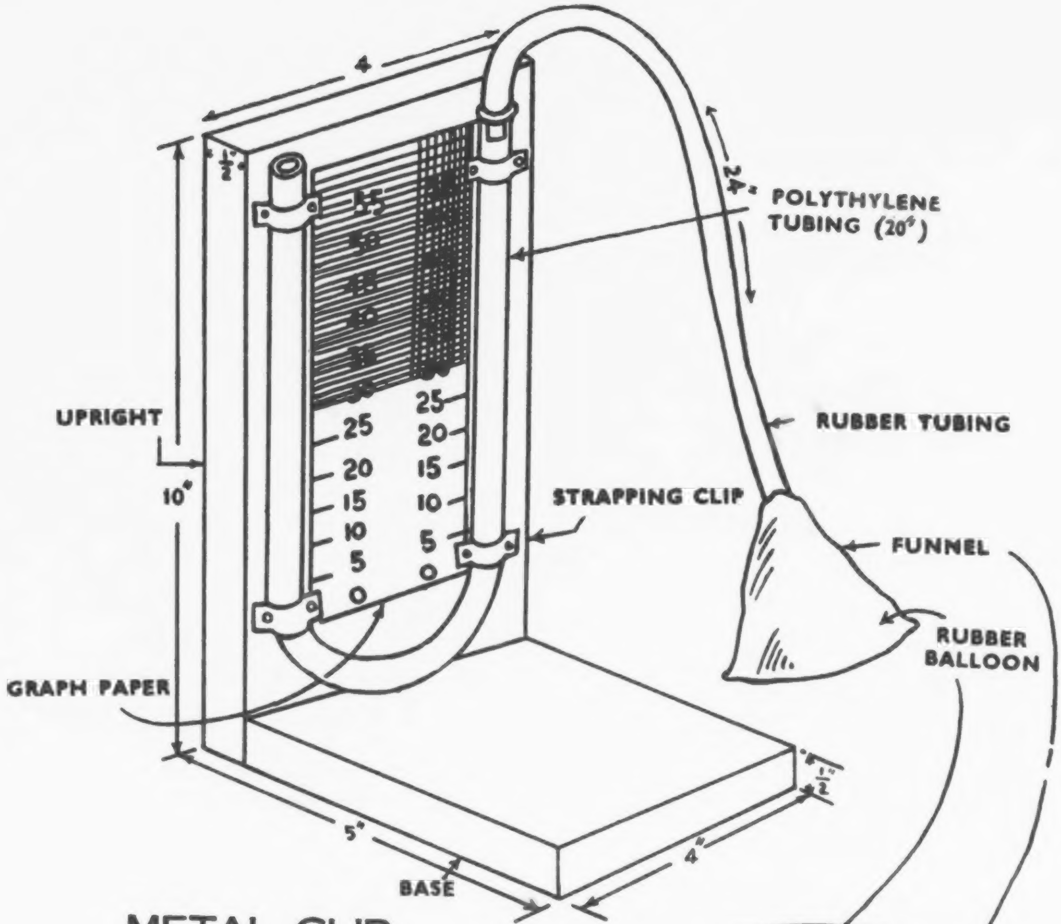
4. Does the temperature of the medum affect the length of time the sound can be heard?

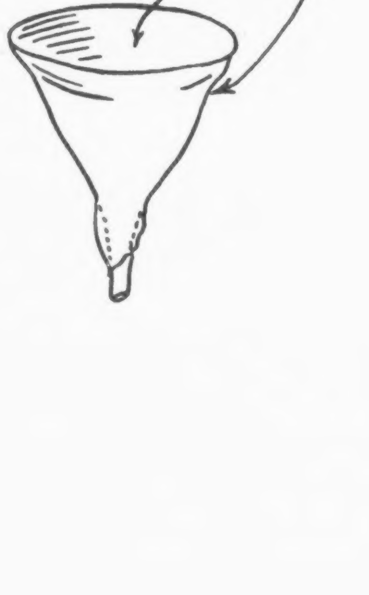
5. Does the height of the water column affect the length of time the sound can be heard?

6. Can you use any liquid other than water and obtain the same results?

7. Can you think of any other way of finding the velocity of sound using the fluorescent tube and without using water any other liquid?

U-TUBE MANOMETER


4
1/2"
24"
POLYTHYLENE TUBING (20")
UPRIGHT
10"
55
50
45
40
35
30
25
20
15
10
5
0
25
20
15
10
5
0
RUBBER TUBING
STRAPPING CLIP
FUNNEL
RUBBER BALLOON
GRAPH PAPER
1/2"
5"
4"
BASE



METAL CLIP

METAL STRAPPING 1.5" LONG

FIG. 1

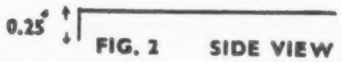


FIG. 2 SIDE VIEW

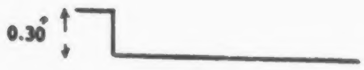


FIG. 3

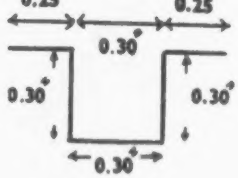

0.25"
0.25"
0.30"
0.30"
0.30"
0.30"

FIG. 4

U-TUBE MANOMETER

Materials required for construction

1. 1/2" × 4" × 5" wood base.
2. 1/2" × 4" × 10" wood upright.
3. 20" polyethylene tubing.
4. One large balloon.
5. 24" of rubber tubing.
6. Four pieces of metal strapping, each 1½" long.
7. One funnel.

Procedure for construction

1. Cut and sand the base and upright Join them with nails.

2. Apply two coats of varnish to the wood pieces and allow it to dry before attaching the tubing.

3. Mark guide lines along the upright 3/4" from each edge and parallel to the edges.

4. Using these guidelines, attach the polyethylene tubing to the upright with the metal strapping as shown. Before attaching the strapping, bend it to the proper shape and punch holes in it for the nails. Be careful not to pinch the tubing with the strapping.

5. Make a graph paper scale wide enough to fit between the vertical parts of the tubing and attach to the upright.

6. To make a U-tube manometer, take a piece of rubber from a large balloon and place it over the mouth of a funnel such that it forms a tight diaphragm. Wrap a few turns of string around it to secure it in place on the funnel. Join the funnel apparatus to the U-tube with a 2' piece of rubber tubing.

Uses in practicals and demonstrations

1. To demonstrate that pressure in a liquid is equal in all directions.
2. To find the specific gravity of liquids which do not mix with water.
3. To measure gas and liquid prssures quantitatively.

Questions for futher study

1. What difference would it make if you used mercury in the U–tube instead of water for measuring specific gravities?

2. Can you use the manometer to show that a gas, just like a liquid, transmits pressures exerted on it equally in all directions?

3. Do different liquids exert the same pressure at equal depths?

4. Can you find the pressure of flowing water?

5. Diffusion of gases can be demonstrated with the manometer. Using the manometer, investigate the pressure created by gas diffusion.

6. How would you use the U–tube to investigate the effect of different climates on the rate of transpiration

7. Without any modifications, will the manometer act as a barometer. If not, how would you modify it so that it would do so?

SHORT INTERVAL TIMER

Materials required for construction

1. 3/4" × 3/4" × 7" wood piece– A.
2. 3/4" × 3/4" × 9⅛" wood piece– B.
3. 3/4" × 3/4" × 3¼" wood piece– C.
4. 1/16" × 1¼" × 1¼" glass piece.
5. 6" of glass tubing 8 mm in diameter.
6. 3/16" bolt 1⅛" long.
7. Two corks 8 mm in diameter.

Procedure for construction

1. Take the 6" piece of glass tubing and check it with the tri-square to make sure that one side is perfectly straight.

2. Filter, boil and refilter a cup of water. Then aerate it and allow it to stand for two days. This procedure is necessary to remove all organic matter from the water which might later produce either CO_2 or O_2 and to bring the dissolved gas level of the water or normal.

3. Soak the two corks in water for two days. At the end of this time insert one cork into the end of the glass tubing Push it in 1/8" past the edge of the tubing and seal the end with sealing wax.

4. Fill the tube with the "treated" water. Insert the second cork part way, remove and reinsert it so that a small bubble of air is captured in the tube. The bubble must be about 1/8" to 3/16" in diameter. If it is not, repeat the above steps.

5. After you have obtained a bubble of the proper size, seal the second end with sealing wax. This way the bubble will remain the same size and the accuracy is assured.

6. Take Block "A" (mentioned above) and carefully check it, making sure that its sides are parallel and straight. This piece must be perfectly square From this piece remove a triangular piece 1/4" × 2⅞" from one side of the piece—see diagram. Be sure that these new surfaces are absolutely straight.

7. Take Block "B" and make sure that it is perfectly square. On one side (see diagram) cut small notches 1/8" deep by using your hand saw at locations 2", 4", 5¼" and 7" from end. Drill a 3/16" hole 1/2" from the end where you started measuring. At the opposite end and on the same surface where you cut the notches, measure off 1/2 of the thickness and remove for 3/4" length. See diagram. Thus you have a board which is 1/4" thick for the last 3/4" of its length. This piece is to fit in block "C".

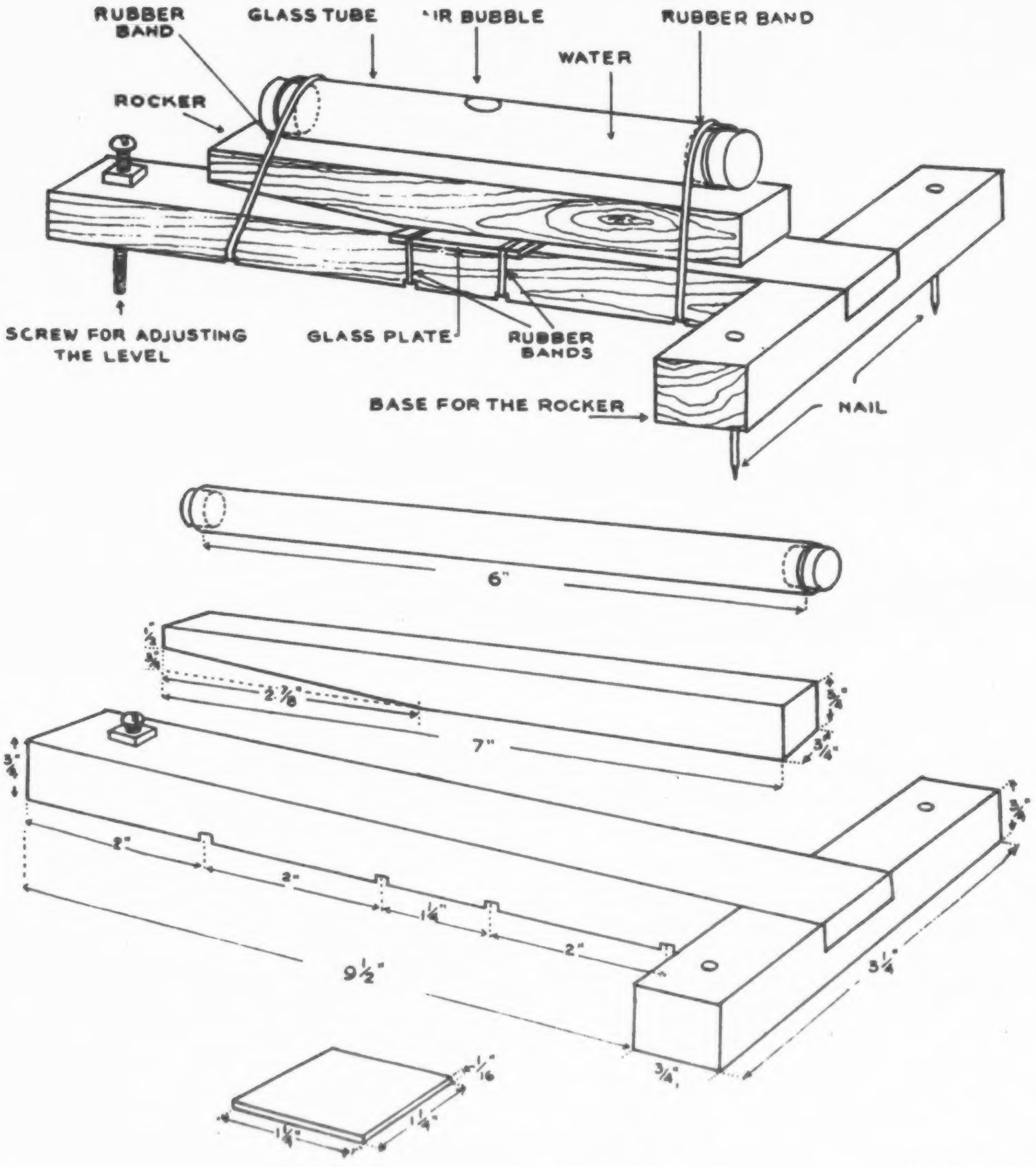
8. Block "C" is to have a notch 3/4" long and 1/2" deep removed from the centre of one side. Blocks "B" and 'C" must fit squarely and tightly. Nail them together.

9. Insert 1¼" long nails into the ends of block "C" so that the ends of the nails stick out of the bottom of this block forming two "feet".

10. Draw a line across the width of block "B", 4" from the end with the hole drilled in it. Mark this line with a heavy pencil so that it can be seen through a coat of varnish.

11. Varnish all the wooden pieces. When varnishing block "B", place one edge of the glass piece on the line (as shown in the diagram) with its other edges sticking out 1/4" over the width

SHORT INTERVAL TIMER


RUBBER BAND
GLASS TUBE
AIR BUBBLE
RUBBER BAND
WATER
ROCKER
SCREW FOR ADJUSTING THE LEVEL
GLASS PLATE
RUBBER BANDS
BASE FOR THE ROCKER
NAIL
6"
1/2
3/4
2 7/8"
7"
3/4"
3/4"
3/4"
2"
2"
1 1/4"
2"
9 1/2"
3/4"
3 1/4"
3/4"
1/16"
1 1/4"
1 1/4"

of block "B" on both sides. When the varnish drys, the glass piece should stick permanently.

12. Insert the bolt into the hole in block "B".

13. Assemble the glass tubing as shown in the diagram.

14. Add the rubber bands to the apparatus as shown in the diagram.

15. Check to make sure that the straight side of the glass tubing is on top.

Calibration

1. Use a stop watch, clock with a second hand or a simple pendulum with 60 swings per minute.

2. Check to see that the tube is level—the bubble will not move in the level position. Check at different locations. Adjustment can be made by using the bolt on the end.

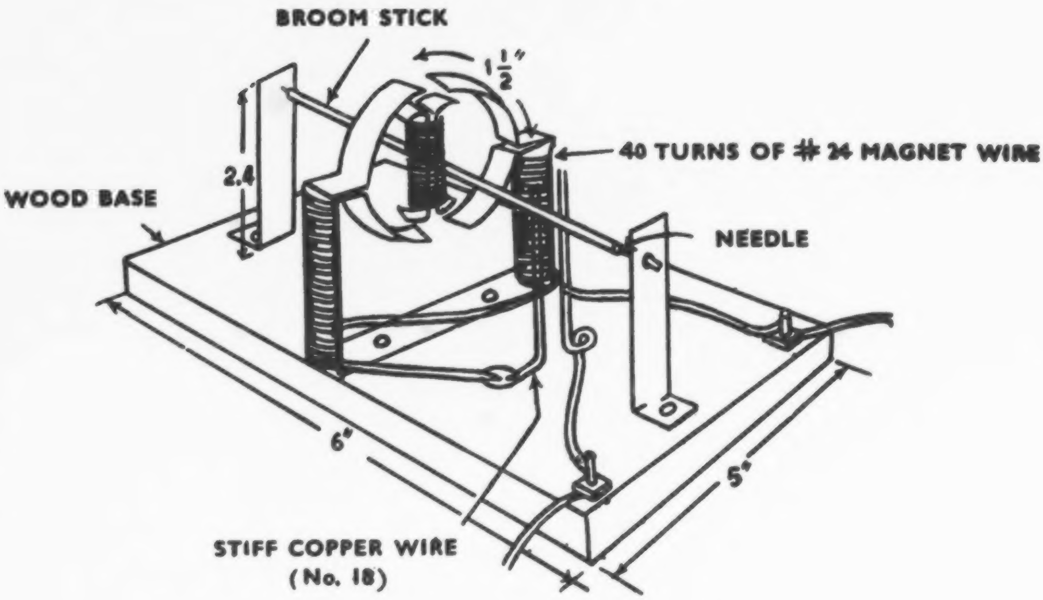
3. To calibrate the 0.1 second interval, move the bubble over to the side with the triangle removed. Mark the centre of the bubble's resting point as "zero", press down on that end for a period of two seconds—one must push quickly and evenly without jerking the apparatus. At the end of the two second interval carefully but quickly release the pressure on the block - the bubble will stop immediately. Mark this spot (the stopping point of the centre of the bubble) and repeat this ten times. The average position of those obtained will be your two second mark. Divide the length between the two points into twenty equal intervals—thus each interval represents 0.1 of a second. Test for a short interval to check the accuracy.

4. To calibrate the 15 second interval again make sure that the tube is level. Bring the bubble to the end which didn't have the triangle removed; mark the centre of the bubble's resting point as "zero". Press quickly and carefully on this end of the block and release after 15 seconds. Mark the 15 sec. spot and repeat this operation 10 times to find the average point. Mark the average point, which is your averaged 15 second mark, and divide the interval between 0 and 15 into 15 equal intervals - each division representing one second.

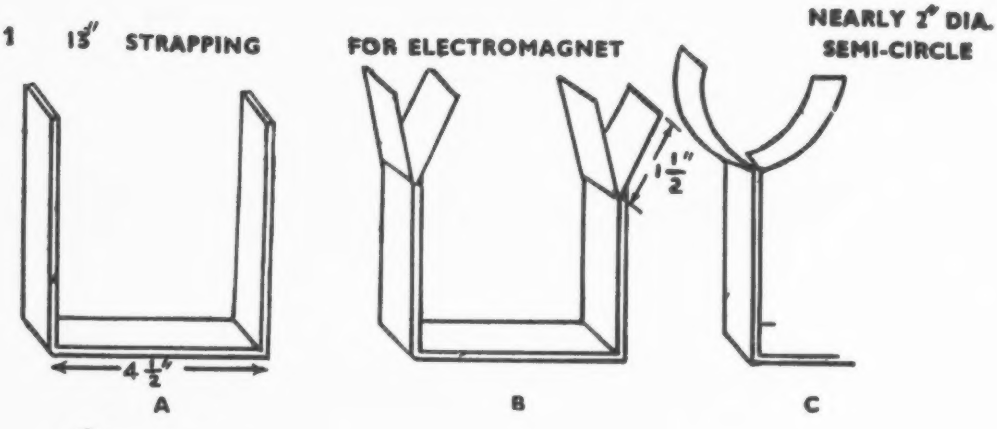
Uses in practicals demonstrations

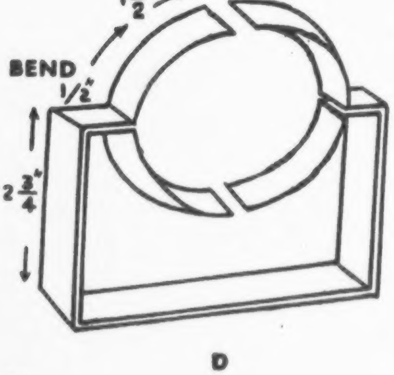
This piece provides you with a timer capable of measuring tenths of seconds accurately up to 15 seconds. Of course, it is not meant to replace a stop-watch. Rather, it is meant to supplement the equipment which is available for student use.

ELECTRIC MOTOR

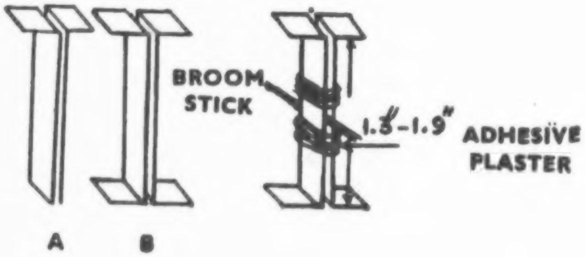

BROOM STICK
1½"
40 TURNS OF # 24 MAGNET WIRE
2.4
WOOD BASE
NEEDLE
6"
5"
STIFF COPPER WIRE
(No. 18)

1 1½" STRAPPING FOR ELECTROMAGNET


NEARLY 2" DIA.
SEMI-CIRCLE
1½"
4½"
A
B
C


1½"
BEND
½"
2¾"
D

(II) ½" STRAPPING FOR ROTOR


BROOM
STICK
1.8"-1.9"
ADHESIVE
PLASTER
A
B

ELECTRIC MOTOR

Materials required for construction

1. Two pieces of strapping 13″ long.
2. Two pieces of strapping 2″ long.
3. Two pieces of strapping 3½″ long.
4. One 3″ broomstick.
5. 24 gauge magnet wire.
6. One 1/2″ × 5″ × 6″ wood base.
7. Two bolts and four nuts.
8. Four screws.
9. 18 gauge enamelled copper wire for brushes.
10. Adhesive tape.
11. One dry cell to run motor.

Procedure for construction

1. Cut, sand and varnish the base.

2. Take the two 13″ strapping pieces and bend them together into a "U" shape so that the arms are 4½″ each and the base 4½″.

3. Measure 1½″ from the free ends and then bend them apart like a "V".

4. Shape the parted ends to form a semicircle of 2″diameter (Fig. B & C).

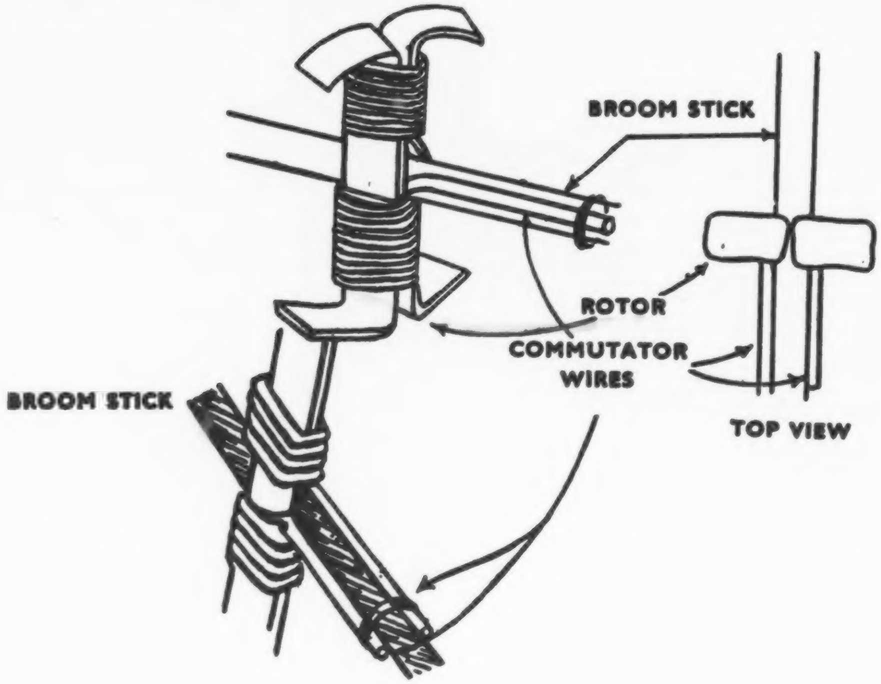
5. Measure 1/2″ down the semicircle and bend the two arms inside (Fig. D).

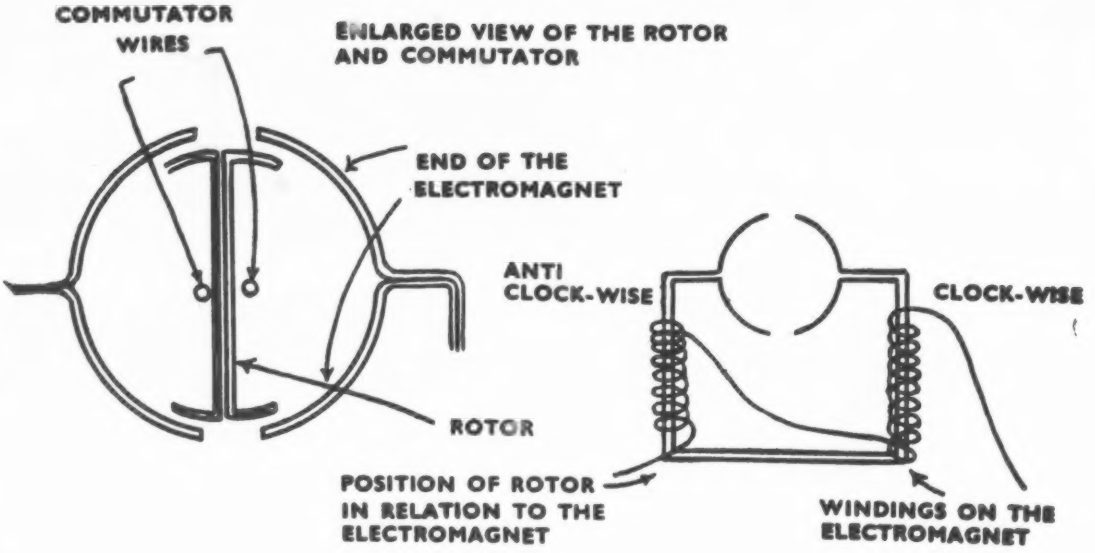
6. Take the 2″ pieces of the rotor and and shape them as shown in Fig.II.

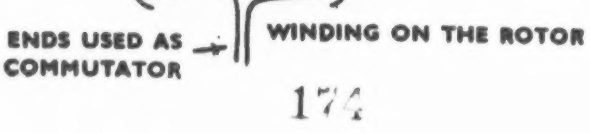
7. Put the broomstick in between them and keep it in position by means of adhesive tape.

8. Take the 3½″ pieces of strapping. Bend 2.7″ part of it at right angles to the remaining part, forming the uprights

9. Drill small holes 2¼″ above the bend in the strapping.


BROOM STICK
ROTOR
COMMUTATOR WIRES
BROOM STICK
TOP VIEW


COMMUTATOR WIRES
ENLARGED VIEW OF THE ROTOR AND COMMUTATOR
END OF THE ELECTROMAGNET
ROTOR
ANTI CLOCK-WISE
CLOCK-WISE
POSITION OF ROTOR IN RELATION TO THE ELECTROMAGNET
WINDINGS ON THE ELECTROMAGNET


ENDS USED AS COMMUTATOR
WINDING ON THE ROTOR

10. Wind 60 turns of No. 26 magnet wire on each arm on the electro-magnet. It should be clockwise on one arm and anti-clockwise on the other.

11. Wind 40 turns of No. 26 wire on the rotor leaving 1" ends of it free. Sand the ends to remove insulation.

12. Place the ends along and on opposite sides of the broomstick. Fix their ends with small pieces of adhesive tape. The plane of these two wires should be at right angles to that of the rotor blades (see diagram).

13. Stick a pin in each end of the broomstick.

14. Fix the electromagnet in the centre of the base parallel to the width. Use nails.

15. Fix the upright bearings as shown in the figure. They must be in a line.

16. Assemble the rotor.

17. Cut two pieces of 18 gauge enamelled copper wire. Sand them to expose the metal. Bend and fix them to the base by means of screws. They must touch the bare copper ends of the rotor on the broomstick.

18. Connect one brush to one end of the wire on the electoromagnet.

19. Connect the second end of the wire on the electromagnet to one of the terminals on the base.

20. Connect the second terminal by means of a wire.

21. Connect the terminals to one good "D" size dry cell and your motor should run.

Uses in practicals and demonstrations

This should be found useful when teaching about electromagnetism and electric motors. It provides a cheap and graphic demonstration of an electric motor and is easy enough to construct that a student with no experience should be able to construct his own working model.

Notes on use and construction

Trouble shooting your motor will, at times, be necessary. There are usually a few important things to be checked before attempting to run the motor. Make sure that the brushes are free from corrosion, and before each demonstration they should be sanded to ensure the best performance. Of course, the connections should be double checked before performing any demonstrations with this piece. If after these things have been done and the motor still doesn't work, check your battery or add another battery and see if it will work. If not, check the winding of your coils and re-read the plans to make sure that you followed them correctly. After the demonstration you may want to ask your students questions like these:

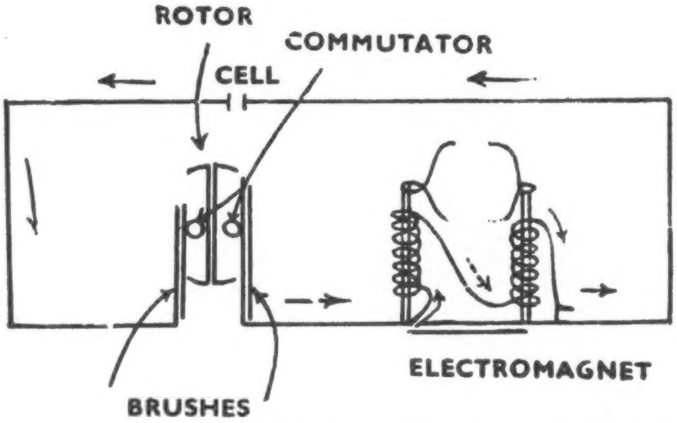
1. What should be the minimum distance between the rotor circle and the stator coil?

2. If the number of windings on the rotor and stator are equal, what will happen?

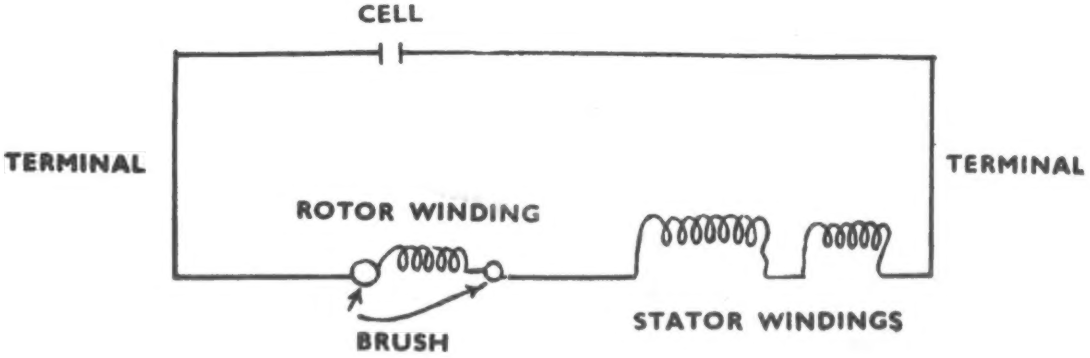
3. What effects will the length of the broomstick have on the operation of this motor?

4. What happens if the commutator ends are kept in a plane parallel to the plane of the rotor?

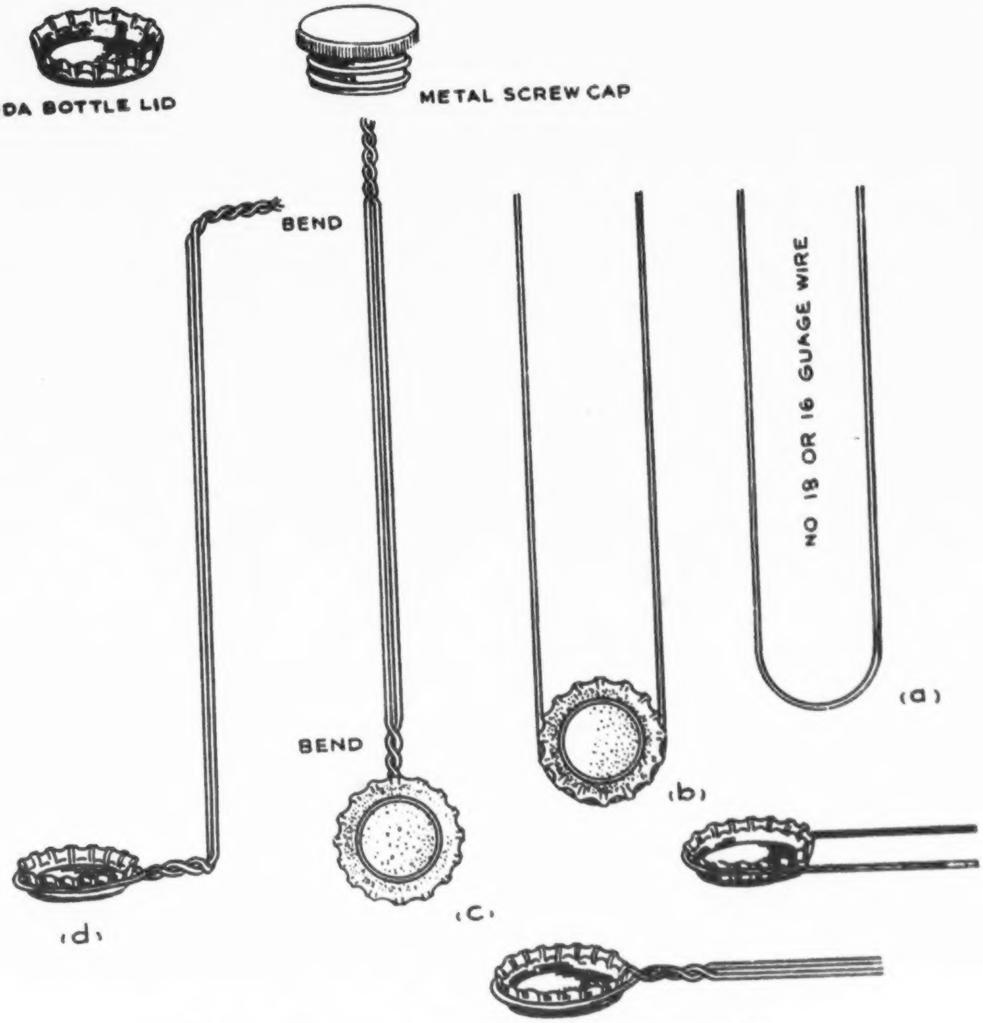
5. State the conditions of the stator and the rotor when current is fed into the coils.


ROTOR
COMMUTATOR
CELL
ELECTROMAGNET
BRUSHES

CIRCUIT DIAGRAMS


CELL
TERMINAL
TERMINAL
ROTOR WINDING
BRUSH
STATOR WINDINGS

DEFLAGRATING SPOON


SODA BOTTLE LID
METAL SCREW CAP
BEND
BEND
NO 18 OR 16 GUAGE WIRE
(a)
(b)
(c)
(d)

DEFLAGRATING SPOON

Materials required for construction

1. Soda bottle cap or metal bottle cap of 1" diameter.
2. One foot of thin wire.

Procedure for construction

1. Make a circle at the middle of the wire to fit the soda lid.

2. Fix the lid in it and twist the end of the wire to the remaining part so that the lid is gripped tightly.

3. Bend the wire away from the bottom of the lid at right angles to the plane of the lid.

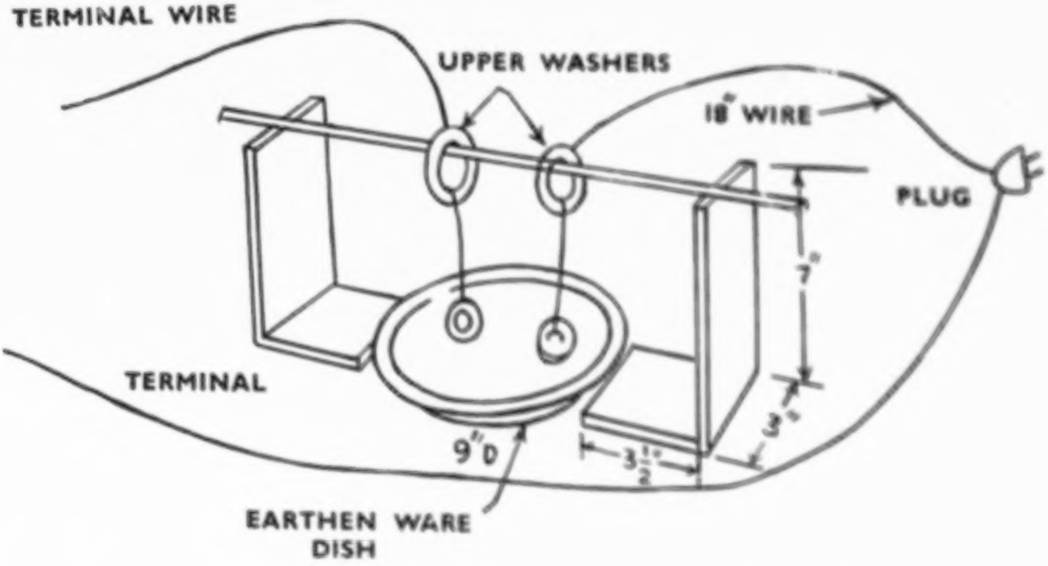
4. Bend the free end of the wire away from the bottle cap to serve as a handle.

CARBON ARC FURNACE

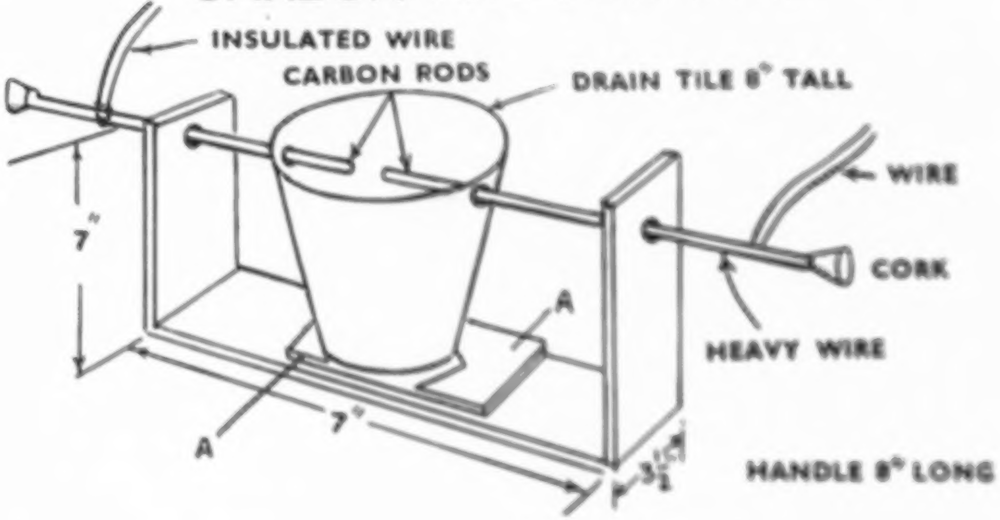
Materials required for construction

1. One earthen (clay) pot.
2. One drain tile.
3. Three 1/2" × 3½" × 7" wood pieces.
4. Two large corks.
5. 16" of heavy wire.
6. Two used "D" size cells.
7. Water rheostat—see plans, this chapter.
8. Electrical wire.

WATER RHEOSTAT


TERMINAL WIRE
UPPER WASHERS
18" WIRE
PLUG
7"
TERMINAL
9"D
3½"
3½"
EARTHEN WARE DISH

CARBON ARC FURNACE


INSULATED WIRE
CARBON RODS
DRAIN TILE 8" TALL
WIRE
7"
CORK
A
HEAVY WIRE
A
7"
3½"
HANDLE 8" LONG

Procedure for construction

1. The bottom dimension of the drain tile that we used was about 3", so we used 3½" wide wood. Construct the wood stand as shown in the diagram.

2. The wood pieces "A" (see diagram) should be cut and nailed into place. They are to hold the tile into position.

3. Drill 1/4" holes in both wood uprights and in the earthen pot.

4. Remove the carbon rods from two used "D" cells.

5. Cut two wire pieces each about 8" long. Attach one carbon rod to each wire by wrapping some light wire around the rod and heavy wire.

6. Fasten the corks securely to the heavy wires. They will serve as insulated handles. Secure the corks with glue or sealing wax.

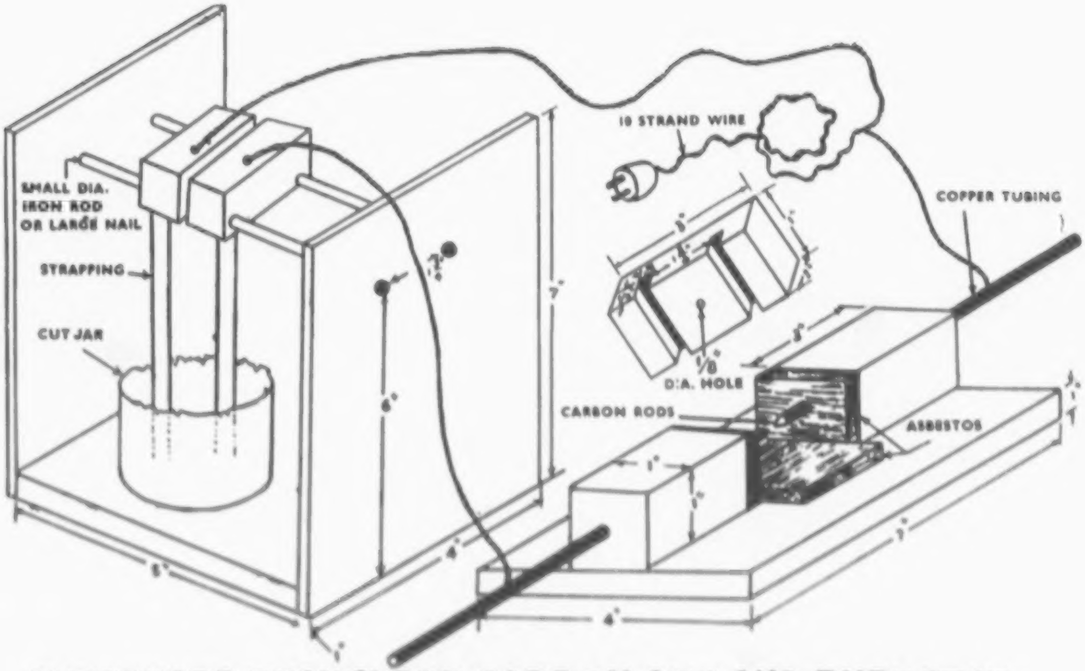
7. The rod-wire-cork assemblies should be threaded into place and the apparatus should be connected to the wall current through the water rheostat.

Caution :

When using the carbon arc, wear dark glasses. Do not touch the metal of the apparatus and be sure that anything that you may place in the arc is insulated and dry.

Uses in practicals and demonstrations

The carbon arc is used to generate heat at temperatures which melt glass easily. It may be used for glass working or for other operations which require intense heat.


SMALL DIA.
IRON ROD
OR LARGE NAIL
STRAPPING
CUT JAR
10 STRAND WIRE
COPPER TUBING
1/8"
D:A. HOLE
CARBON RODS
ASBESTOS
7"
6"
5"
4"
1"
3"
4"
7"

ALTERNATE DESIGN FOR CARBON ARC AND RHEOSTAT

SALT WATER RHEOSTAT

Materials required for construction

1. Two 1/2" × 3" × 7" wood uprights.
2. 1/2" × 3" × 12" wood base.
3. One earthen (clay) bowl.
4. One bamboo piece 14" in length.
5. Four large washers.
6. Insulated wire.

Procedure for construction

1. Cut and sand the wooden pieces given in 1 and 2 above.

2. Nail the uprights to the base as shown in the diagram.

3. Connect the washers with insulated wire as shown in the diagram.

4. Place the bamboo piece over the ends of the upright as illustrated and thread the washers on the bamboo as shown.

5. Place the connected washers in the earthen bowl and fill the bowl with water.

6. Connect the electrical terminals as shown.

7. Put a little salt in the water and plug-in the rheostat. Add more salt as needed and manipulate the amount of current desired by changing the distances between the two washers in the bowl.

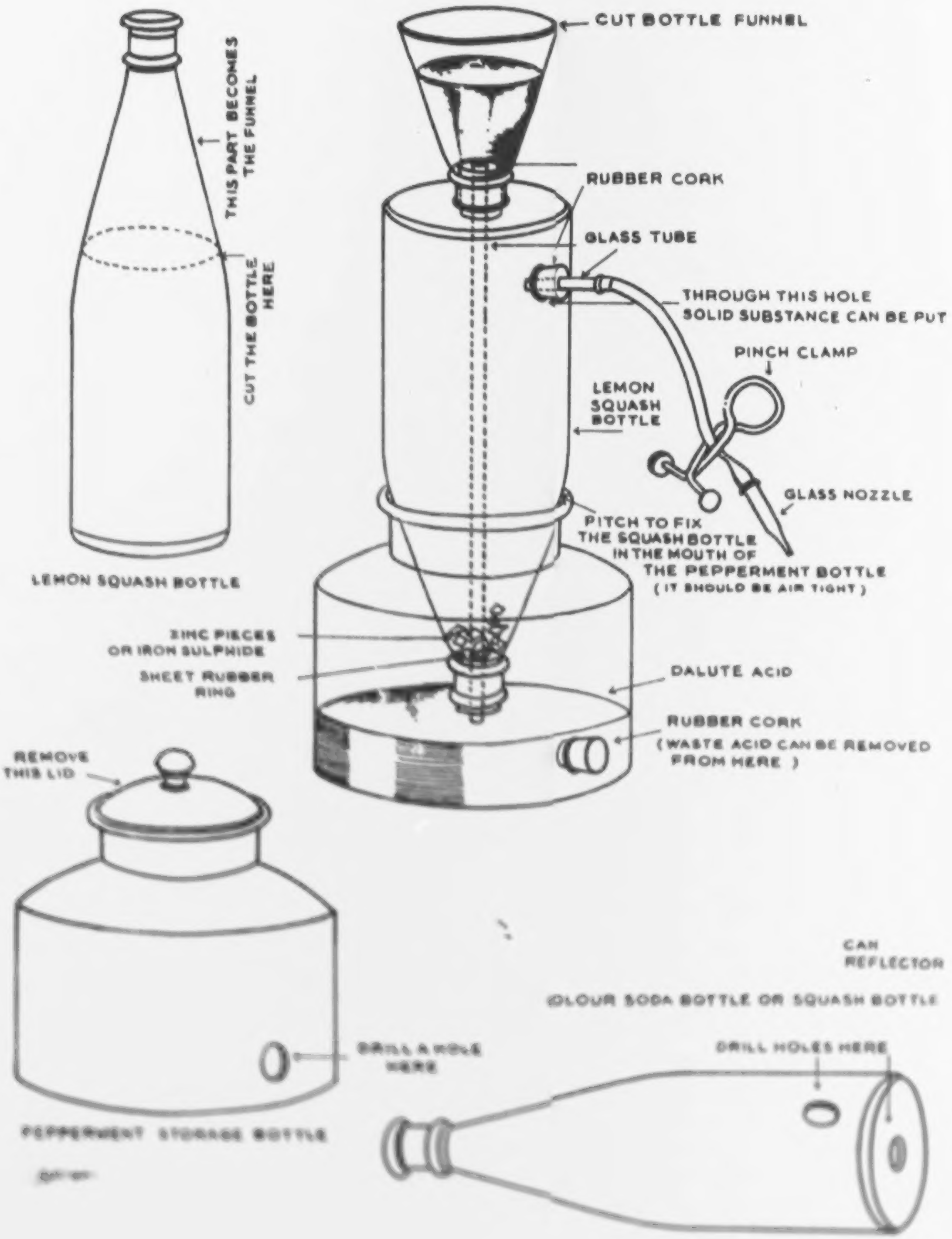
Uses in practicals and demonstrations

This rheostat is needed when used in conjunction with the carbon arc lamp or furnace. It provides enough resistance so that wall current may be used.

Notes on use and construction

When using this piece of apparatus you should first adjust the washers so that they are fairly widely separated. Then add small amounts of salt to the water until current begins to flow. The amount of current may be adjusted by manipulating the distances between the washers but try to avoid adding more salt to the solution after the current has begun to flow.

KIPPS GAS GENERATOR


THIS PART BECOMES THE FUNNEL
CUT THE BOTTLE HERE
LEMON SQUASH BOTTLE
CUT BOTTLE FUNNEL
RUBBER CORK
GLASS TUBE
THROUGH THIS HOLE SOLID SUBSTANCE CAN BE PUT
PINCH CLAMP
LEMON SQUASH BOTTLE
GLASS NOZZLE
PITCH TO FIX THE SQUASH BOTTLE IN THE MOUTH OF THE PEPPERMENT BOTTLE
(IT SHOULD BE AIR TIGHT)
ZINC PIECES OR IRON SULPHIDE
SHEET RUBBER RING
DALUTE ACID
RUBBER CORK
(WASTE ACID CAN BE REMOVED FROM HERE)
REMOVE THIS LID
DRILL A HOLE HERE
PEPPERMENT STORAGE BOTTLE
CAN REFLECTOR
COLOUR SODA BOTTLE OR SQUASH BOTTLE
DRILL HOLES HERE

KIPP'S GAS GENERATOR

Materials required for construction

1. One peppermint bottle with wide mouth (bottom 6" diameter and the mouth 4" diameter).
2. One lemon squash bottle 8" high.
3. One bottle with conical neck.
4. 14" of glass tubing.
5. Two one-holed rubber stoppers.
6. One rubber stopper without a hole.
7. Rubber tubing.

Procedure for construction

1. Make a hole in the side of the peppermint bottle just above the bottom.

2. Close it with the holeless rubber stopper.

3. Make a hole on the side of the squash bottle just above the bottom.

4. Drill another hole in the centre of the bottom.

5. Cut the bottle with the conical neck just below the cone. This conical part serves as a funnel.

6. Insert 12" of glass tubing in the one-holed rubber stopper and connect the bottom of the squash bottle and the funnel as shown in the diagram.

7. Fix the mouth of the squash bottle in the neck of the peppermint bottle (see diagram).

8. Seal the connection with the black pitch ("wadakilu") it is sold in the hardware shop. It is a black solid which melts on heating and the hot liquid looks like tar.

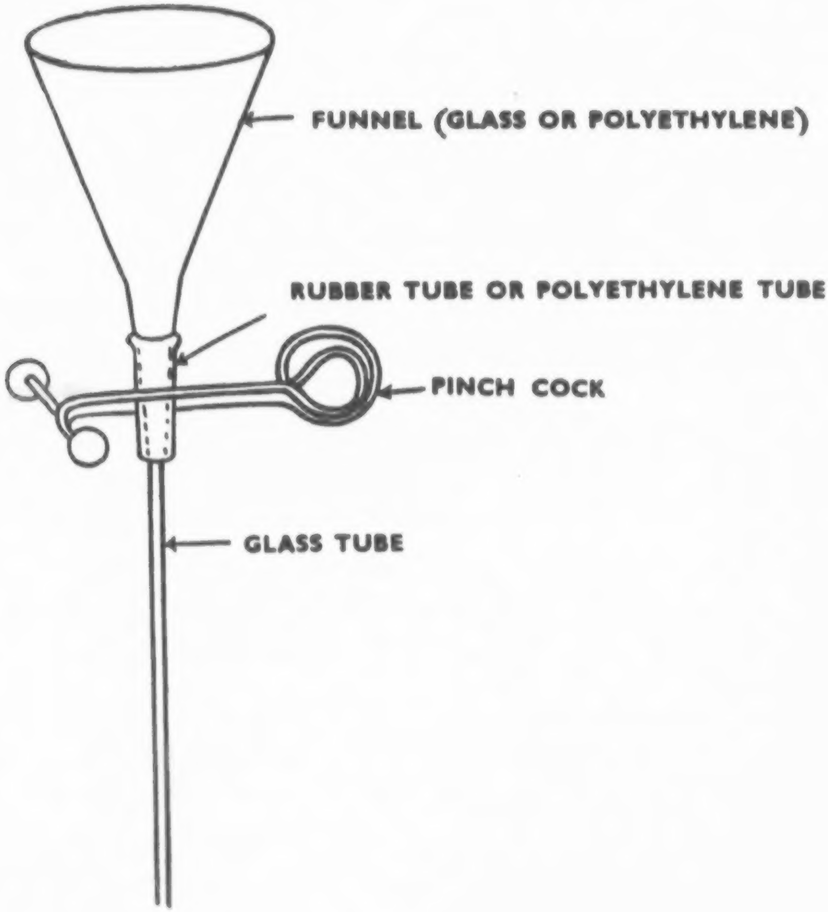
9. Assemble the other parts as shown in the figure. Take a rubber piece with a hole in its centre and insert it into the mouth of the squash bottle. It will serve as a "platform" for the solid chemical used (zinc, iron sulfide etc).

10. You may use a metal grip clip as the pinch cock or you may improvise one from heavy wire.

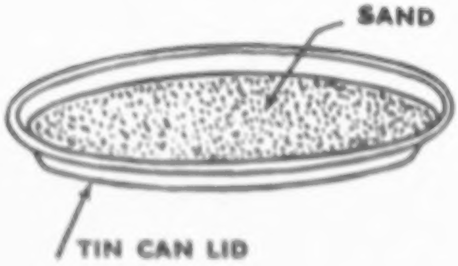
Uses in practicals and demonstrations

This piece is a required piece of apparatus in your syllabus. However, by improvising one, the student should be better able to come to an understanding of the principles involved in its operation. It will also serve adequately if you don't have this piece in your laboratory.

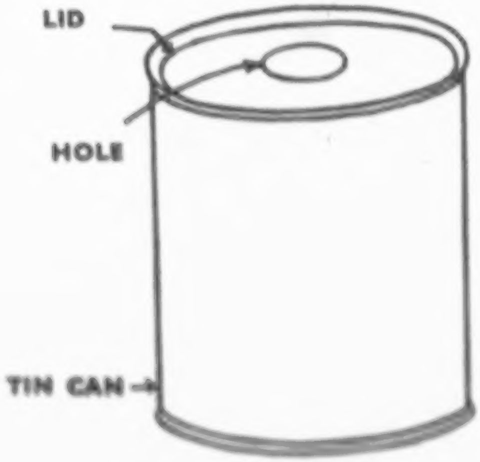
DROPPING FUNNEL


FUNNEL (GLASS OR POLYETHYLENE)
RUBBER TUBE OR POLYETHYLENE TUBE
PINCH COCK
GLASS TUBE

SAND BATH


SAND
TIN CAN LID

WATER BATH


LID
HOLE
TIN CAN

DROPPING FUNNEL

Materials required for construction

1. One glass or plastic funnel.
2. 6" to 8" length glass tube.
3. One pinch cock.
4. A few inches of rubber tubing.

Procedure for construction

1. For construction see diagram.

SAND BATH

Materials required for construction

One tin can lid of 4" to 6" in diameter.

Procedure for construction

1. See diagram.

WATER BATH

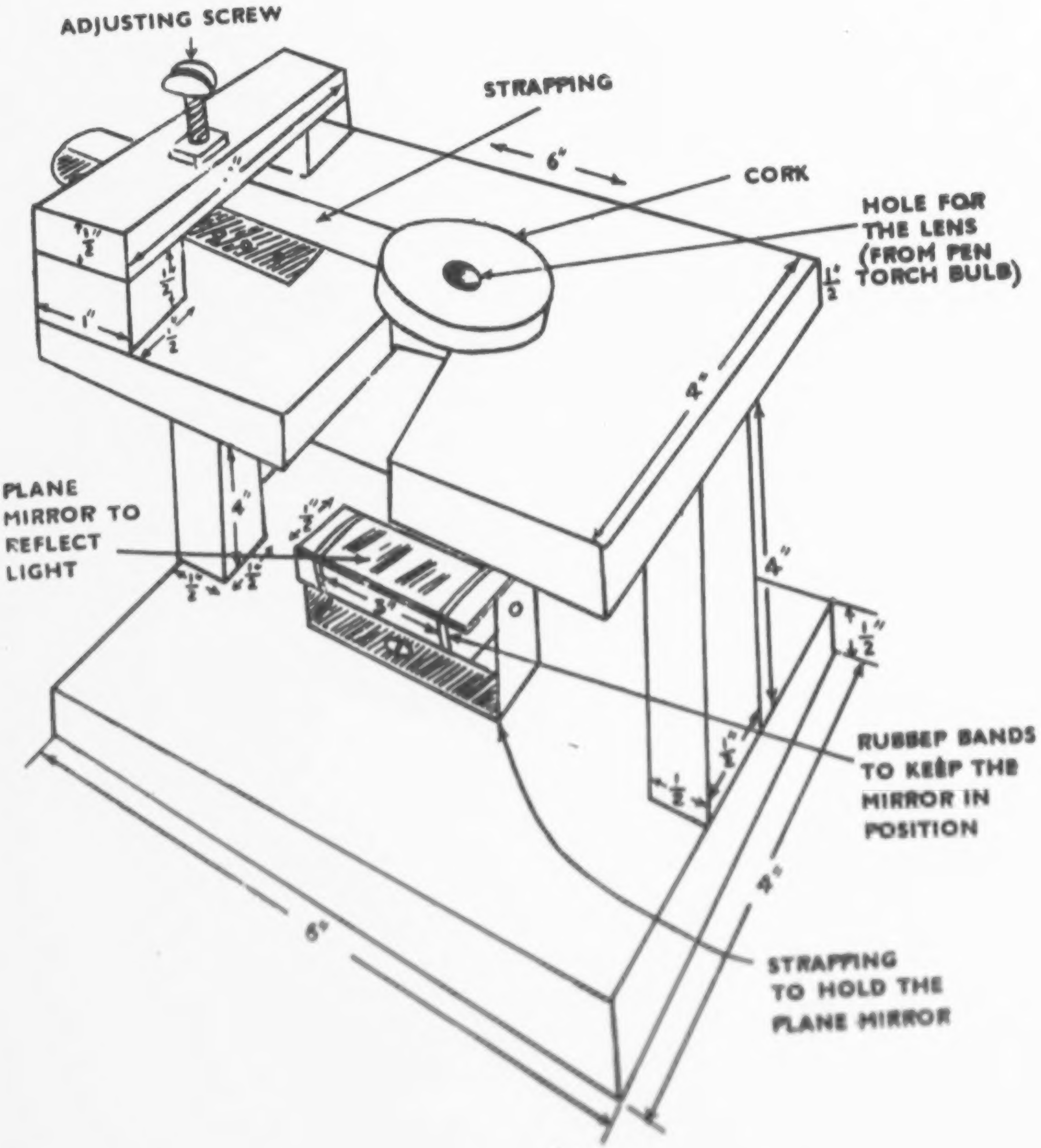
Materials required construction

1. One tin can with lid.

Procedure for construction

1. A hole of 1" diameter is made in the lid of the can.

SIMPLE MICROSCOPE


ADJUSTING SCREW
STRAPPING
6"
CORK
HOLE FOR THE LENS (FROM PEN TORCH BULB)
1/2"
1"
4"
PLANE MIRROR TO REFLECT LIGHT
2"
RUBBER BANDS TO KEEP THE MIRROR IN POSITION
STRAPPING TO HOLD THE PLANE MIRROR
6"

SIMPLE MICROSCOPE

Materials required for construction

1. Two 1/2" × 4" × 6" wood pieces.
2. Two 1/2" × 1/2" × 4" wood pieces.
3. 1/2" × 1/2" × 4" wood pieces.
4. One penlight bulb.
5. Two 1/2" × 1/2" × 1" wood pieces.
6. One 3/16" diameter bolt and nut 3½" long.
7. 8" of metal strapping.
8. Mirror piece 1/2" × 3".
9. Two rubber bands.

Procedure for construction

1. Cut and sand wood pieces given in 1, 2, 3 and 6 above.

2. Take five inches of strapping and bend up at 90° one inch from each end. Use a large nail to punch nail holes in the 3" section of the bracket. Also, punch small holes on the 1" sections which will later receive the mirror mounting. Nail the bracket to the centre of the 4" × 6" wood base as shown in the diagram.

3. Place the mirror strip on the 1/2" × 1/2" × 3" wood piece and secure with rubber bands. Place this assembly between the uprights of the bracket which you just completed and tack it in place such that it can be rotated to get the best light.

4. Nail the 1/2" × 1/2" × 4" uprights to the base.

5. The 1/2" × 4" × 6" wood piece is the stage. Cut a notch 1" wide and 2" deep as shown in the drawing.

6. Nail the 1/2" × 1/2" × 1" blocks to the narrow (3") end of the stage as in the drawing.

7. Nail this assembly to the 1/2" × 1/2" × 4" wood uprights.

8. Drill a 3/16" hole in the middle of the 1/2" × 1/2" × 4" piece. This is to hold the adjusting screw.

9. Place the metal strapping on the stage as shown. Nail it on to the stage and be sure that the part nailed down does not come outside to interfere with the slide. Nail the 1/2" × 1/2" × 4" piece for the hardening, heat the nut and place over the hole and allow the wax to harden. Thread in the bolt—the end of the bolt touching the strapping should be filed to a point.

10. Take the penlight bulb and remove the front portion by scratching around the circumference and then breaking. This is your lens.

11. Make a 1" circle out of a block of wood and it no thicker than 1/2". Drill a 3/16" hole in the centre and widen with a file until the penlight lens fits snugly.

12. Cut a slit into the 1" circle allowing it to fit onto the strapping. You may have to put tape on the end of the strapping to get a tight fit.

13. Put the lens into the 1" eyepiece, attach to strapping and your scope is ready for use.

Questions for further study

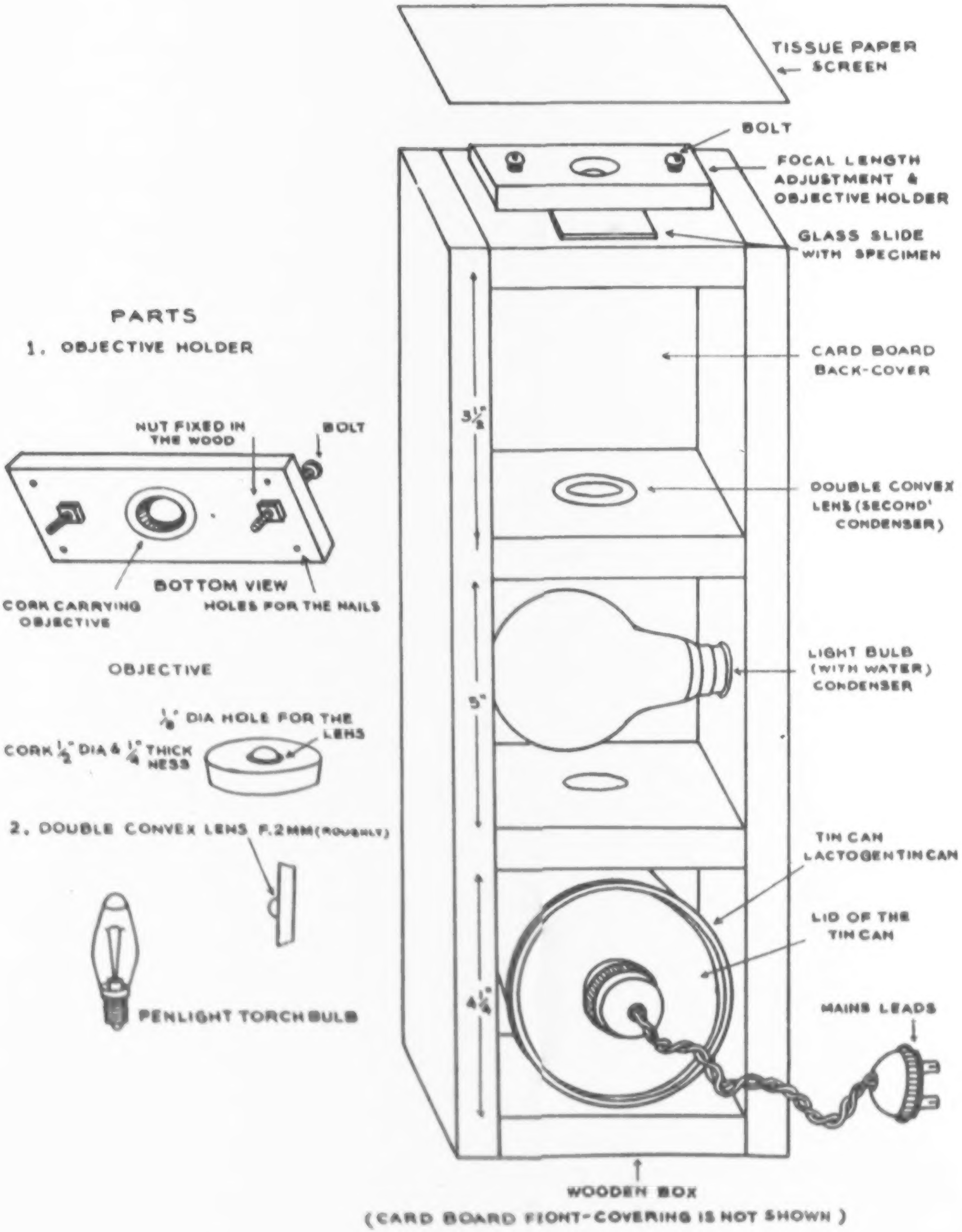
1. How can the lens magnify the objects?

2. What sort of image is formed by the simple microscope?

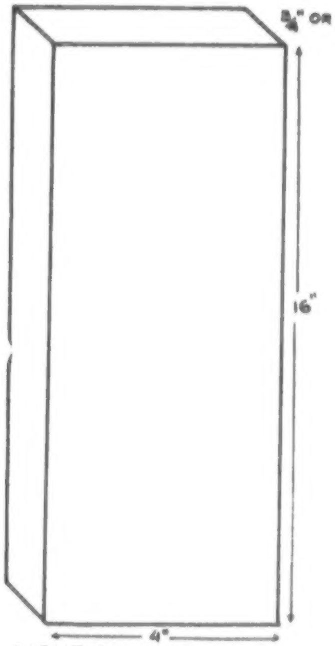
3. Where should the slide be placed? Why?

4. Glass beads can be used as lenses. Prepare different size glass beads making sure that they are perfectly round and do not contain air bubbles. The glass bead is placed between two pieces of strapping so that the two holes in the strapping come over and below the bead. How does the magnification vary with the size of the bead?

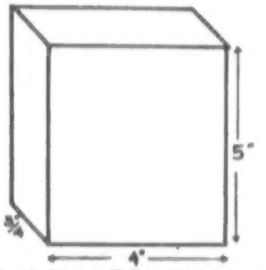
MICRO PROJECTOR


TISSUE PAPER SCREEN
BOLT
FOCAL LENGTH ADJUSTMENT & OBJECTIVE HOLDER
GLASS SLIDE WITH SPECIMEN
CARD BOARD BACK-COVER
DOUBLE CONVEX LENS (SECOND' CONDENSER)
LIGHT BULB (WITH WATER) CONDENSER
TIN CAN LACTOGEN TIN CAN
LID OF THE TIN CAN
MAINS LEADS
3½"
5"
4¾"
WOODEN BOX
(CARD BOARD FRONT-COVERING IS NOT SHOWN)
PARTS
1. OBJECTIVE HOLDER
NUT FIXED IN THE WOOD
BOLT
BOTTOM VIEW
CORK CARRYING OBJECTIVE
HOLES FOR THE NAILS
OBJECTIVE
⅛" DIA HOLE FOR THE LENS
CORK ½" DIA & ¼" THICK NESS
2. DOUBLE CONVEX LENS F.2MM (ROUGHLY)
PENLIGHT TORCH BULB

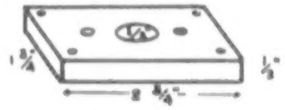
3. WOODEN BOX



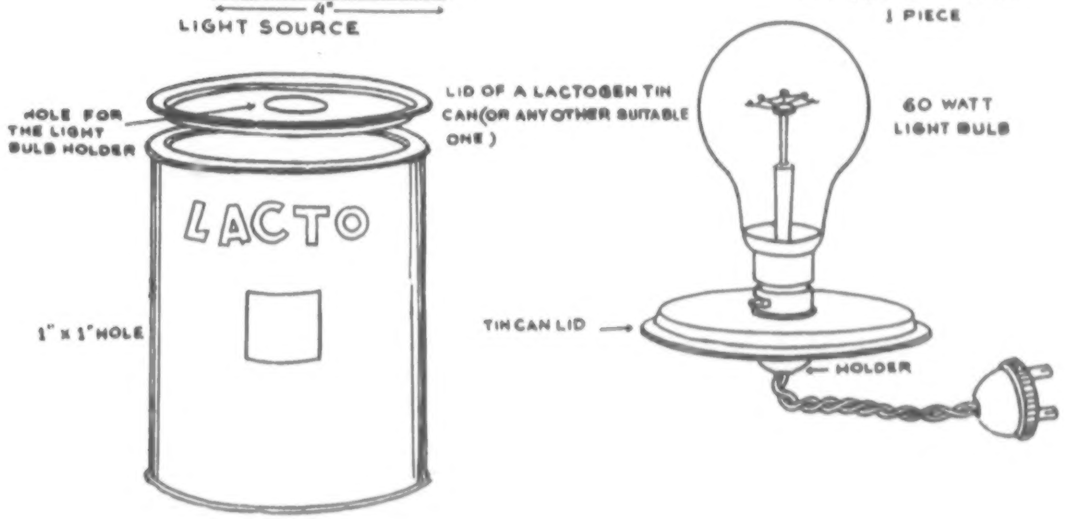
LIGHT SOURCE



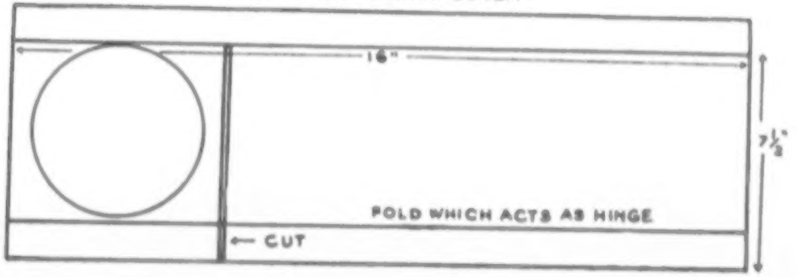
1 PIECE FOR THE BASE 3 PIECES FOR THE REST
THESE THREE MUST HAVE HOLES IN THE MIDDLE
(1/2" DIAMETER HOLES)



OBJECTIVE HOLDER
1 PIECE


HOLE FOR THE LIGHT BULB HOLDER
LID OF A LACTOGEN TIN CAN (OR ANY OTHER SUITABLE ONE)
LACTO
1" x 1" HOLE
60 WATT LIGHT BULB
TIN CAN LID
HOLDER

FRONT CARD BOARD COVER


16"
7 1/2"
FOLD WHICH ACTS AS HINGE
CUT

MICROPROJECTOR

Materials required for construction

1. Two 3/4" × 9½" × 5½" wood sides.
2. Two 3/4" × 5½" × 6" wood ends.
3. 3/4" × 6" × 11" wood bottom.
4. One small "Champion Oats" tin.
5. One penlight bulb.
6. One 60 watt light bulb.
7. One light bulb socket.
8. Electrical wire.
9. One plug.
10. One burned out light bulb.
11. One rubber stopper.
12. One cork.
13. Strapping.
14. One piece cardboard 4" × 2".
15. One piece light cardboard 6" × 2".
16. Black paint.

Procedure for construction

1. Cut a hole in the centre of one of the end pieces, and construct the box according to the diagram.

2. Cut the cardboard top, and cut a hole in it as shown.

3. Paint the inside black.

4. Cut a hole in the lid of the tin, so that the light blub and socket will be held there (Figure 1). Cut a window in the side of the tin as shown in Figure 1. The light bulb should be just inside the window.

5. Clean the burned-out light bulb, fill with water, and cork it.

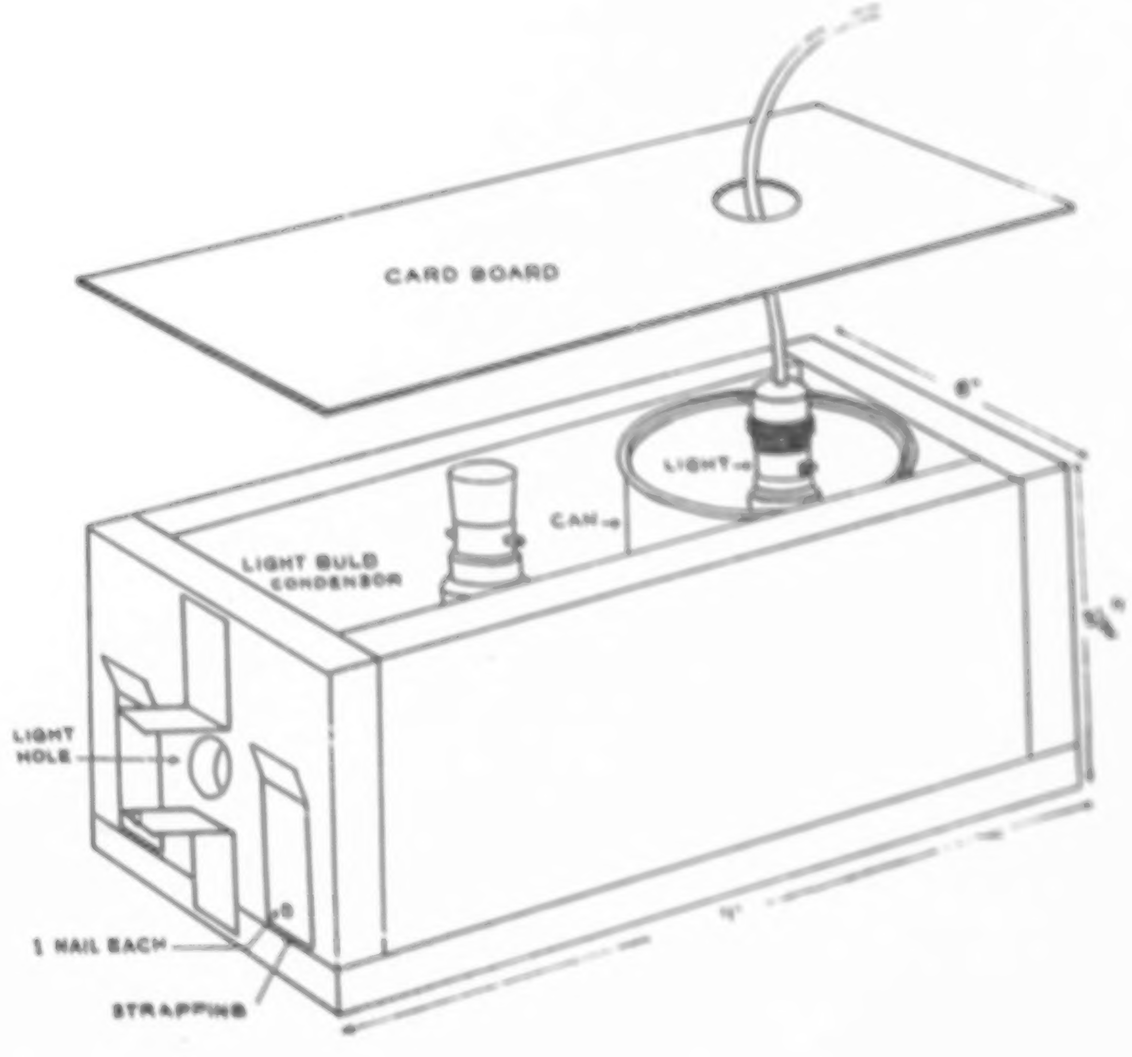
6. Make a stand for it by curving a piece of cardboard (6" × 2") and fastening it as in Figure 2. The water filled bulb now sits on the stand, and may be placed in the box as shown in the main diagram. This bulb acts as a condensing lens for the light coming from the tin.

7. The botanical or zoological specimen slide is to be placed on the front end of the box. Fix pieces of strapping as shown in the diagram. The two flat pieces will hold a slide in place. The two bent pieces will hold the lens in place.

8. The lens is the same one or same type which is used for the simple micro-

MICRO PROJECTOR

(DIFFERENT DESIGN)


CARD BOARD
6"
LIGHT
CAN
LIGHT BULB CONDENSOR
LIGHT HOLE
1 NAIL EACH
STRAPPING
9"

scope. It is taken from the tip of a penlight bulb. To mount it on the front of the box, slice a disk off one end of a cork (dark area, figure 3), mount it on a flat piece of cardboard (4"×2") See Figure 4. Drill a small hole in the centre of the cork, through the cardboard, so that the lens may be placed there. Be sure that no light can escape around the edges of the lens.

9. With the lens mounted this way it may be attached to the front of the box.

10. Cut two slits in the cardboard (Figure 4), and slide the piece into the two bent pieces of strapping on the front of the box.

11. Prepare a screen by making a small wooden frame as shown in Figure 5, and by attaching a very thin transluscent paper as shown (we used the thin protective sheet of a stencil paper).

12. Place a glass slide underneath the strapping clips on the front of the projector. Now close all windows, turn out the lights, and darken the room. Place the screen a couple of feet in front of the box, and turn on the light.

13. A magnified image of the glass slide specimen will appear on the screen' For greater light concentration you may place a lens (optical bench lens holder) in front of the light bulb condensor. You must experiment with this projector in order to attain success with it. You must adjust the light source in the tin, you must adjust the light bulb condensing lens and the penlight lens, and you must adjust the slide specimen. However, with just a little practice you will be able to use this projector for class demonstrations.

Uses in practicals and demonstrations

To project a magnified picture of cells, cross sections of leaves, roots, stems etc., on a screen allowing a large number of students to observe and participate in these types of demonstrations.

MICRO PROJECTOR
(DIFFERENT DESIGN)

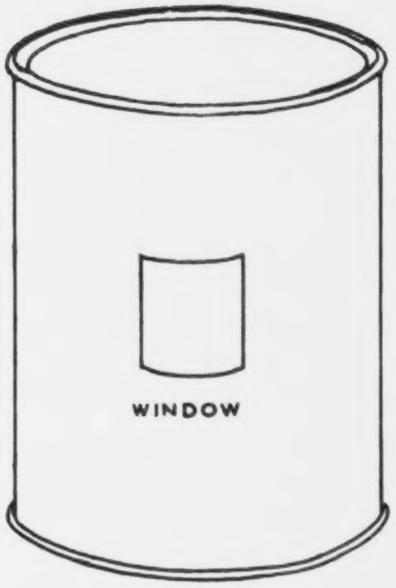
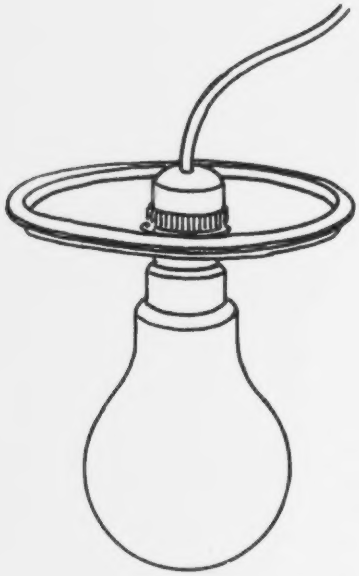


FIG. 1.



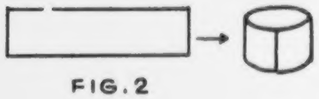


FIG. 2

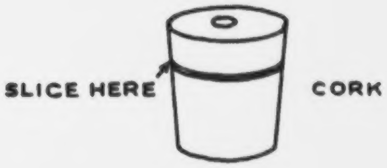

SLICE HERE
CORK

FIG. 3

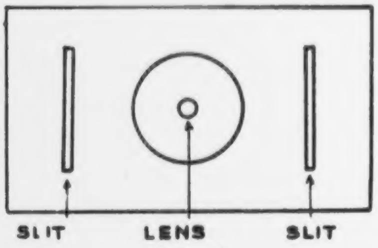

SLIT
LENS
SLIT

FIG. 4

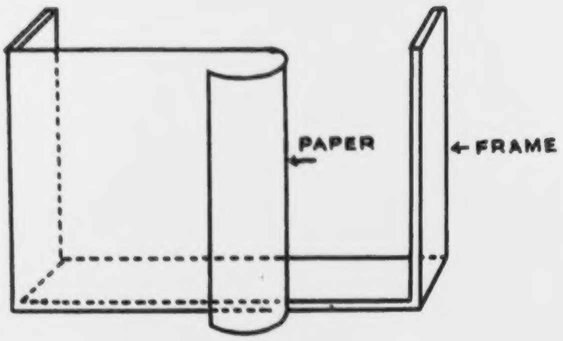
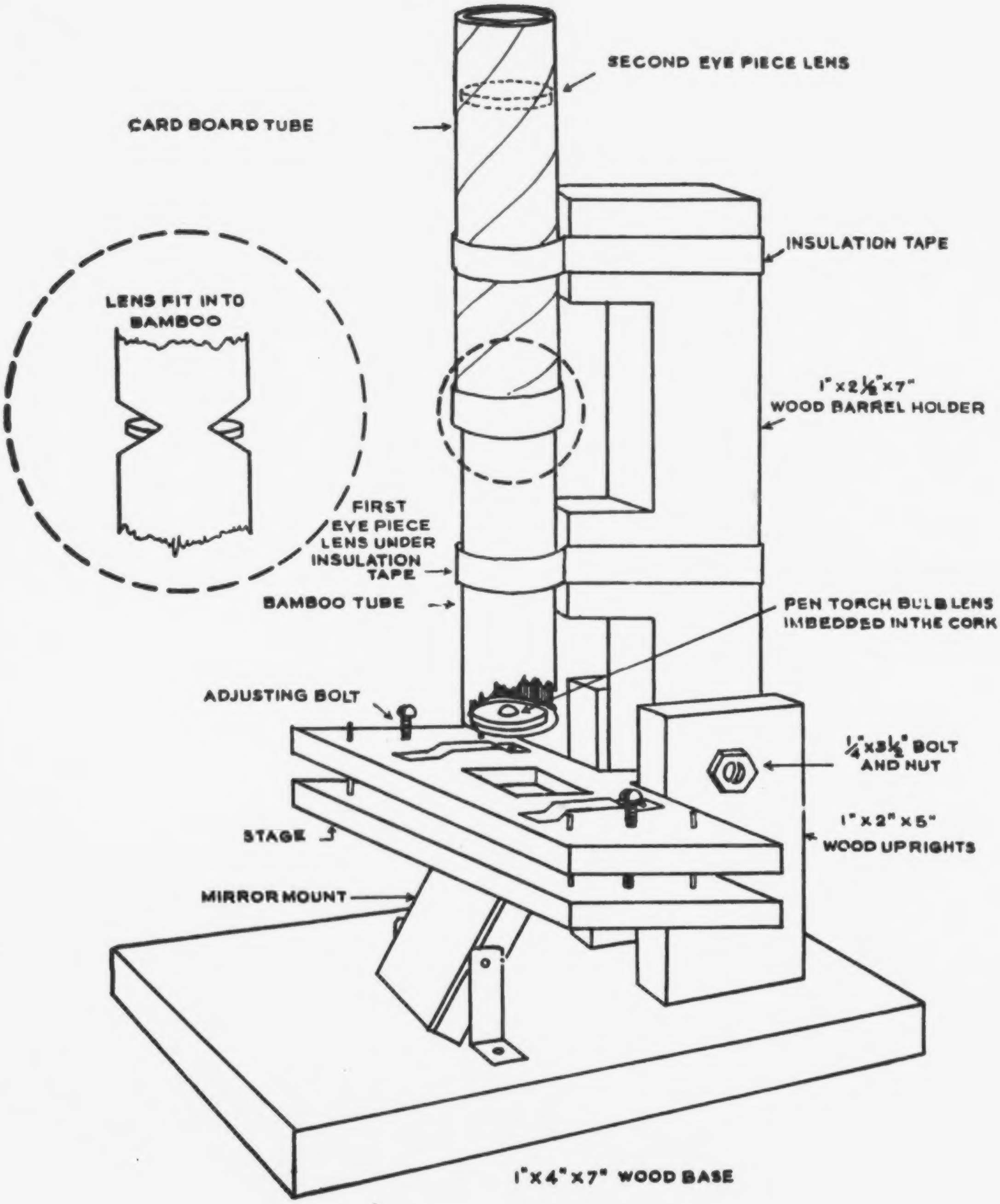

PAPER
FRAME

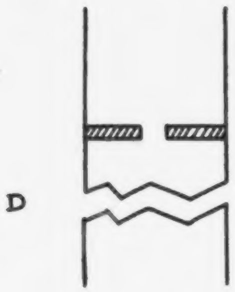
FIG. 5

COMPOUND MICROSCOPE


SECOND EYE PIECE LENS
CARD BOARD TUBE
INSULATION TAPE
LENS FIT INTO BAMBOO
1"x2½"x7" WOOD BARREL HOLDER
FIRST EYE PIECE LENS UNDER INSULATION TAPE
BAMBOO TUBE
PEN TORCH BULB LENS IMBEDDED IN THE CORK
ADJUSTING BOLT
¼"x3½" BOLT AND NUT
STAGE
1"x2"x5" WOOD UPRIGHTS
MIRROR MOUNT
1"x4"x7" WOOD BASE

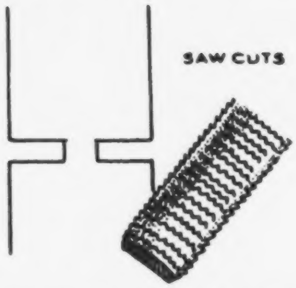
COMPOUND MICROSCOPE - PARTS

FIG. 2



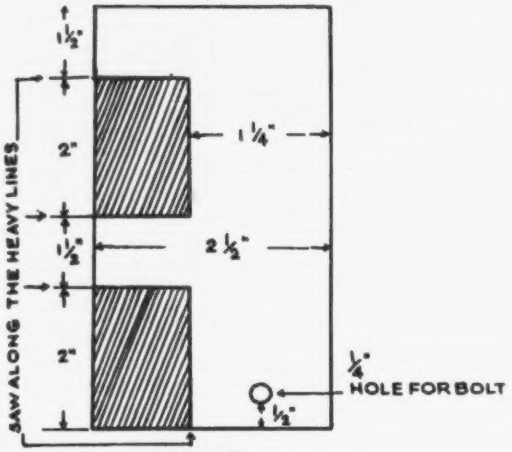
SAW TWO CUTS ON OPPOSITE SIDES OF THE BAMBOO TUBE MAKING SURE NOT TO CUT THE BAMBOO IN TO TWO,

FIG. 3



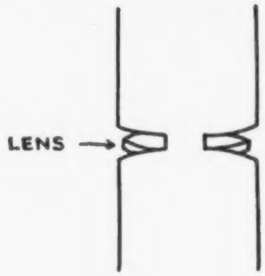
WITH THE WOOD RASP ENLARGE THE SAW CUTS UNTIL THE PIECE LENS CAN FIT AS SHOWN IN FIG. E

FIG. 5


1½"
2"
1¼"
1½"
2½"
2"
¼" HOLE FOR BOLT
½"
SAW ALONG THE HEAVY LINES

USE A CHISEL TO CLEAN OUT THE SHADED AREAS

FIG. 4



BAMBOO TUBE WITH THE SAW CUTS ENLARGED AND THE EYE PIECE LENS FITTED IN TO PLACE,

FIG. 6

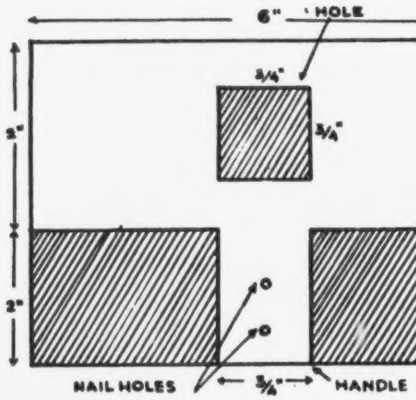
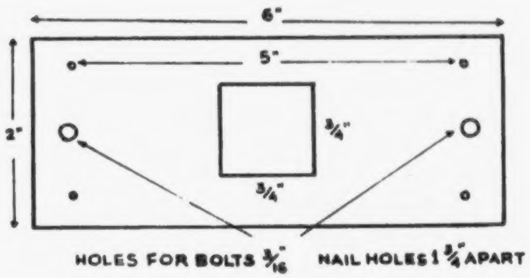

6"
HOLE
3/4"
3/4"
2"
2"
NAIL HOLES
3/4"
HANDLE

FIG. 7


6"
5"
2"
3/4"
3/4"
HOLES FOR BOLTS 3/16"
NAIL HOLES 1 3/4" APART

COMPOUND MICROSCOPE

Materials required for construction

Barrel.

1. One double convex lens from a pen torch bulb.
2. One 1" cork.
3. Two watchmaker's lenses with short focal lengths (5–10 cm).
4. One bamboo tube approximately 8" long and whose interior diameter is slightly less than the diameter of the eyepiece lenses.
5. Insulation tape.
6. Heavy cardboard.

Barrel Holder

7. 1" × 2½" × 7" wood piece.

Stage

8. 1/2" × 4" × 6" wood base piece.
9. 1/2" × 2" × 6" wood stage piece.
10. Two 2" pieces of metal strapping.
11. Two 3/16" nuts and bolts 1½" long.
12. Two 1" pieces of metal strapping.
13. 1½" thin wire nails.

Stand

14. 1" × 4" × 7" wood base.
15. Two 1" × 2" × 5" wood uprights.
16. 1/2" × 1" × 2" wood mirror mount.
17. Two pieces of metal strapping 2½" long.
18. One 1" × 2" mirror.
19. 1/4" nut and bolt 3½" long.

Procedure for construction

Note: The distance between the objective lens and the first eyepiece lens is a definite unvarying distance the length of which can be found with the formula $D = S + F_e$ where is found in the formula:

$$\frac{1}{S} = \frac{-1}{(f + .1f)} + \frac{1}{f} \text{ or } S = 11f,$$

where f is the focal length of the objective lens and F_e is the focal length of the first eyepiece lens.

The second eyepiece can be placed later without the use of a formula.

1. *Fitting the eyepiece lens in the bamboo* At the distance 'D' (see note above) from one end of the bamboo tube, make a saw cut less then halfway through the tube. Repeat this operation on the other side. Make sure not to cut all the way through.

2. Take the wood rasp and enlarge the cut on one side until it is large enough for the eyepiece lens to fit into the tube firmly.

In might also be necessary to enlarge the cut on the other side so that the lens will fit in such a way that the exact centre of lens is in the centre of the tube.

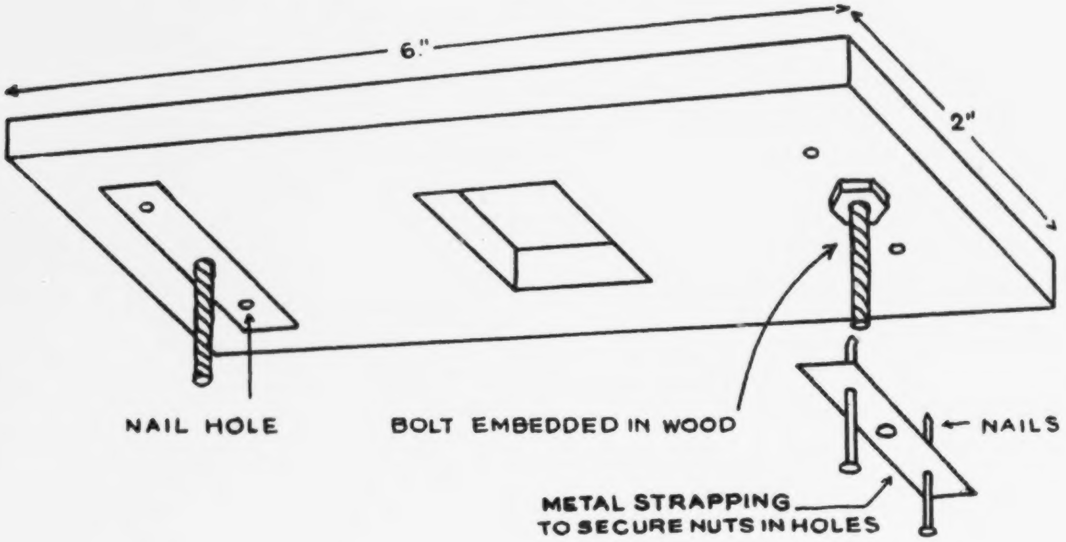
3. Make sure that the lens is in the centre of the tube and also that it is perpendiculer to the longitudinal axis of the tube.

4. Insert the lens and cover the cuts with insulation tape.

5. *Fitting the objective*: Fit the cork into the bamboo tube. Cut–off any part of the cork which extends more than 5 millimeters out of the tube.

COMPOUND MICROSCOPE PARTS

FIG. 8


6."
2"
NAIL HOLE
BOLT EMBEDDED IN WOOD
NAILS
METAL STRAPPING
TO SECURE NUTS IN HOLES

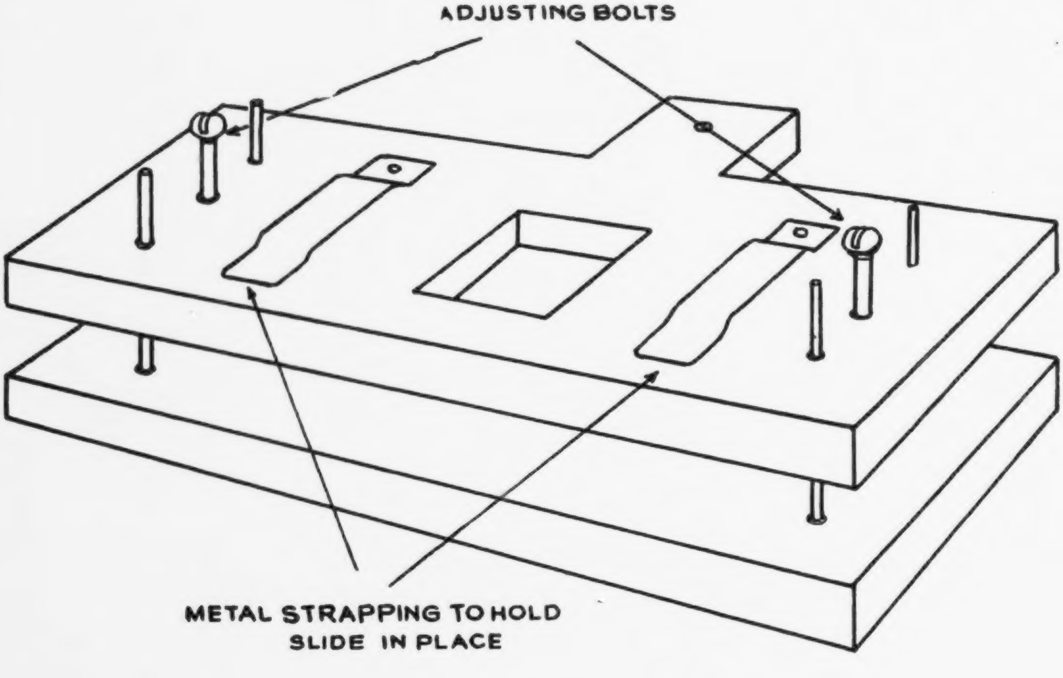

ADJUSTING BOLTS
METAL STRAPPING TO HOLD
SLIDE IN PLACE

FIG. 9

6. With a cork borer of diameter slightly less than the diameter of the pen-torch light bore a hole in the exact centre of the cork.

7. Force the lens into the hole so that it remains there firmly. Make sure that the eyepiece and the objective lenses are parallel.

8. Insert the cork into the bamboo so that the centres of the two lenses are exactly the distance "D" apart and that the cork fills the entire hole in the tube.

9. Cut and sand the 6″ × 2½″ × 7″ wood piece.

10. With a saw, cut the lines indicated in Figure 5.

11. With a chisel, cut out the unnecessary wood as indicated.

12. Cut the base piece of the stage as indicated in Figure 6.

13. Using a nail as a drill bit, drill two holes in the handle of the base piece to attach it to the barrel holder.

14. Chisel a 3/5″ square hole in the base piece so that the centre of that hole will be directly below the centre of the lenses.

15. *Moving Stage*: Chisel a 3/4″square hole in the centre of this piece checking to see that its centre is directly below centre of the lenses.

16. Using a 1½″ thin wire nail as a drill bit, drill four holes in the moving stage in the positions indicated in Figure 7.

17. With a 3/16″ drill bit, drill two holes in this piece in the positions indicated in the figure.

18. On the under side of moving stage, widen the 3/16″ hole until the nut fits into it. Drill a hole through the 1″ pieces of strapping and nail over the net. Make sure that the bolt turns freely in the nut (see Figure 8).

19. Bend the 9″ pieces of strapping as shown in Figure 9 and nail them to the stage as indicated. These pieces are to hold the slide in place.

20. Using the four nail holes as guides, nail the four 1½″ nails to the base piece. Cut-off the hands of these nails. See that the stage moves up and down freely as you turn the adjusting bolts.

21. *Stand*: Cut, square and smooth all the wooden pieces in 14, 15 and 16.

22. Drill a 1/4″ hole through the two uprights and the barrel holder so that the 1/4″ bold will fit through all three and barrel holder will turn on that axis (see Figure 12).

23. Nail the two uprights to the stand as indicated in Figure 11.

24. Assemble the mirror mount as shown in Figure 12.

25. Find the proper place for the mirror by temporarily mounting the barrel holder in the uprights and finding where the lens is. Place the mirror mount so that the centre of the mirror is directly beneath the centre of the objective lens.

26. Paint or varnish the entire apparatus.

27. Attach the mirror to the mirror mount with glue.

28. *Final Adjustments*: Nail the stage to the barrel holder as shown in Fig. 13.

29. Attach the barrel to the holder with insulation peat.

COMPOUND MICROSCOPE PARTS

FIG. 10

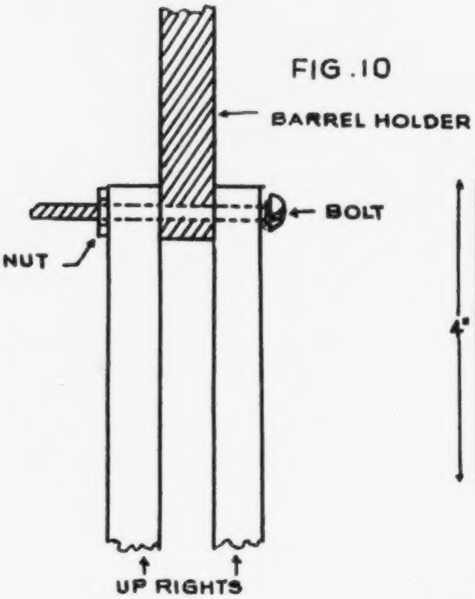

BARREL HOLDER
BOLT
NUT
UP RIGHTS

FIG 11

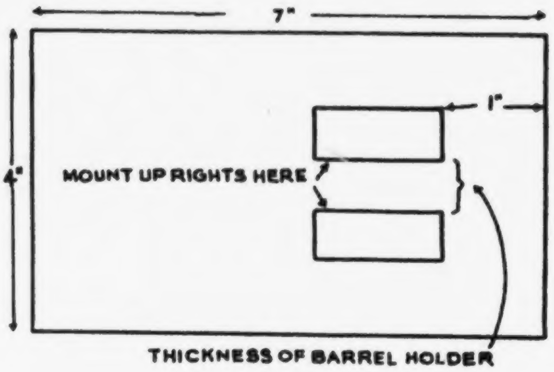

7"
4"
1"
MOUNT UP RIGHTS HERE
THICKNESS OF BARREL HOLDER

FIG. 12

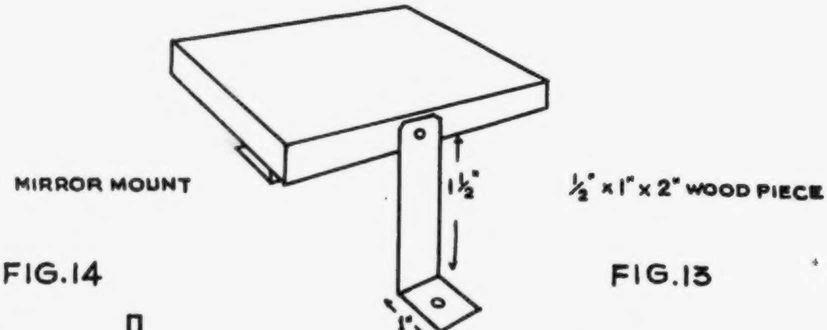

MIRROR MOUNT
1½"
½" x 1" x 2" WOOD PIECE
1"

FIG. 14

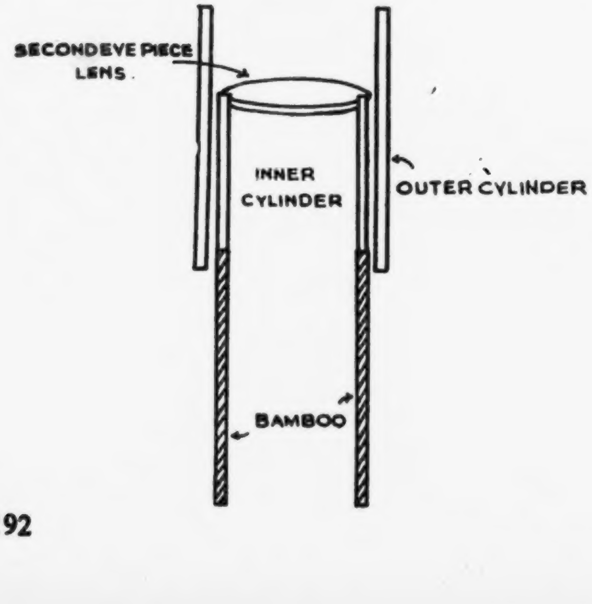
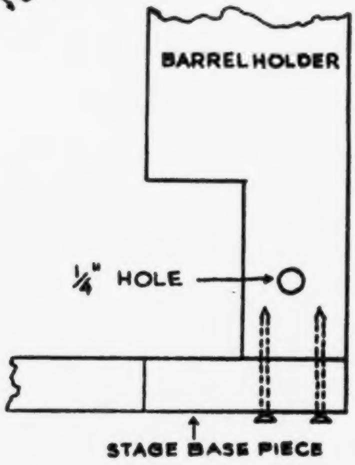

SECOND EYE PIECE LENS.
INNER CYLINDER
OUTER CYLINDER
BAMBOO

FIG. 13


BARREL HOLDER
¼" HOLE
STAGE BASE PIECE

30. *Focusing*: With a slide held securely on the stage, focus the image by adjusting the moving stage. Place your eye on the open top of the bamboo and adjust until you see a clear image of the slide. Move your eye back until the image fills the entire field and make more minor adjustments.

31. *The second eyepiece lens*: Take the other watchmaker's lens and place on top of the open bamboo tube. If the image fills the field, attach. However, if it does not fill the field, move the lens up and down until you find the place where the image is the largest.

32. The most important factor in the clearness of the image is the distance between the objective and the first eyepiece lens. If the image is not perfectly clear, this distance may need final adjustment.

33. Roll some heavy cardboard into a cylinder the length of which should be the distance from the top of the bamboo to the lens at the correct position and whose diameter should be just less than the outside diameter of the bamboo tube. Place the lens on top of this cylinder.

34. Roll another cylinder which will fit snugly over the bamboo tube and the first cylinder. This cylinder will hold the smaller cylinder in place and also hold the lens on top of the small cylinder (see Figure 14).

Uses in practicals and demonstrations

1. For use in examining micro-organisms.
2. To demonstrate the construction of a compound microscope.
3. To study the optics of the microscope.

Questions for further study

1. What are the conditions governing the length of the microscope tube?

2. What should be done in order to reduce the length of the tube?

3. What kind of lenses must we use in order to achieve greater magnification?

4. Why is there a distortion in the image?

5. What is spherical aberration? Can you observe it? What is chromatic aberration? Can you observe it? How can you decrease these distortions?

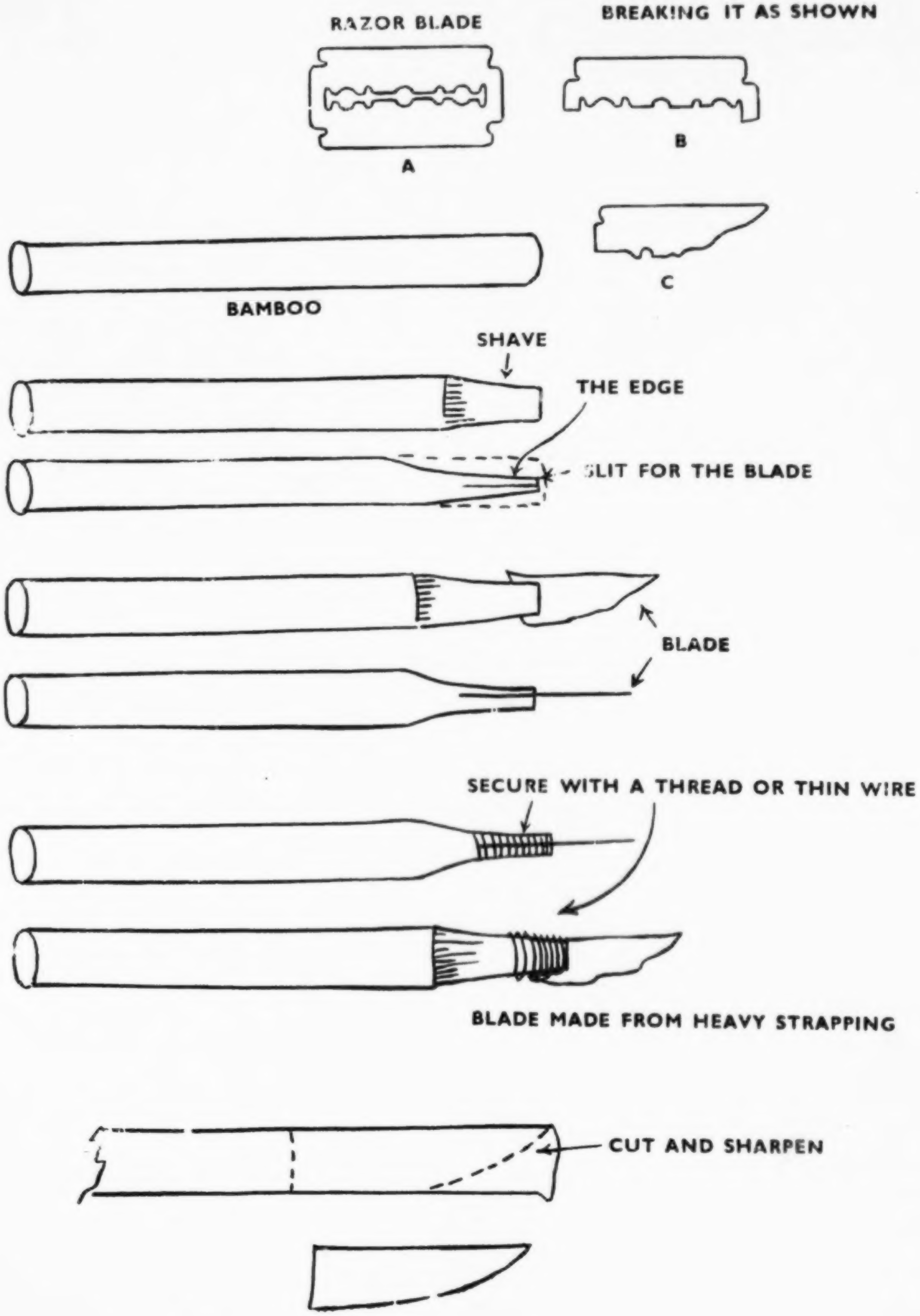
6. Where do you think the image forms?

7. What would you suggest to get a brighter image?

8. Why should you keep your eye a bit higher than the top of the lens?

SCALPEL

MAKE A BLADE FOR THE SCALPEL BY BREAKING IT AS SHOWN


RAZOR BLADE
A
B
C
BAMBOO
SHAVE
THE EDGE
SLIT FOR THE BLADE
BLADE
SECURE WITH A THREAD OR THIN WIRE
CUT AND SHARPEN

BLADE MADE FROM HEAVY STRAPPING

DISSECTING KIT

Materials required for construction

1. Bamboo pieces.
2. One razor blade.
3. Strong thread.
4. Sewing needle.
5. Metal strapping.
6. Heavy wire.
7. 3 litre tin.
8. Candle wax.
9. Hinges.
10. Two 1/2″ × 5″ × 7″ wood pieces.
11. Four 1/2″ × 1″ × 5″ wood pieces.
12. Four 1/2″ × 1″ × 6″ wood pieoes.

Procedure for construction

1. *Scalpel* : Take a bamboo piece 5″ long and 5/16″ in diameter and carefully split one end about 3/8″.

2. Shave the bamboo to form a slope on either side of the slit.

3. Break a discarded razor blade in half lengthwise and insert this piece into the slit. Secure the blade in position by wrapping strong thread of soft iron wire around the bamboo.

4. *Note*: Strapping could also be useful in making a blade. A piece of thick strapping 2½″ in length can be shaped and sharpened to form the scalpel blade.

5. *Forceps* : Select a piece of dry bamboo about 5″ long and 1/4″ thick.

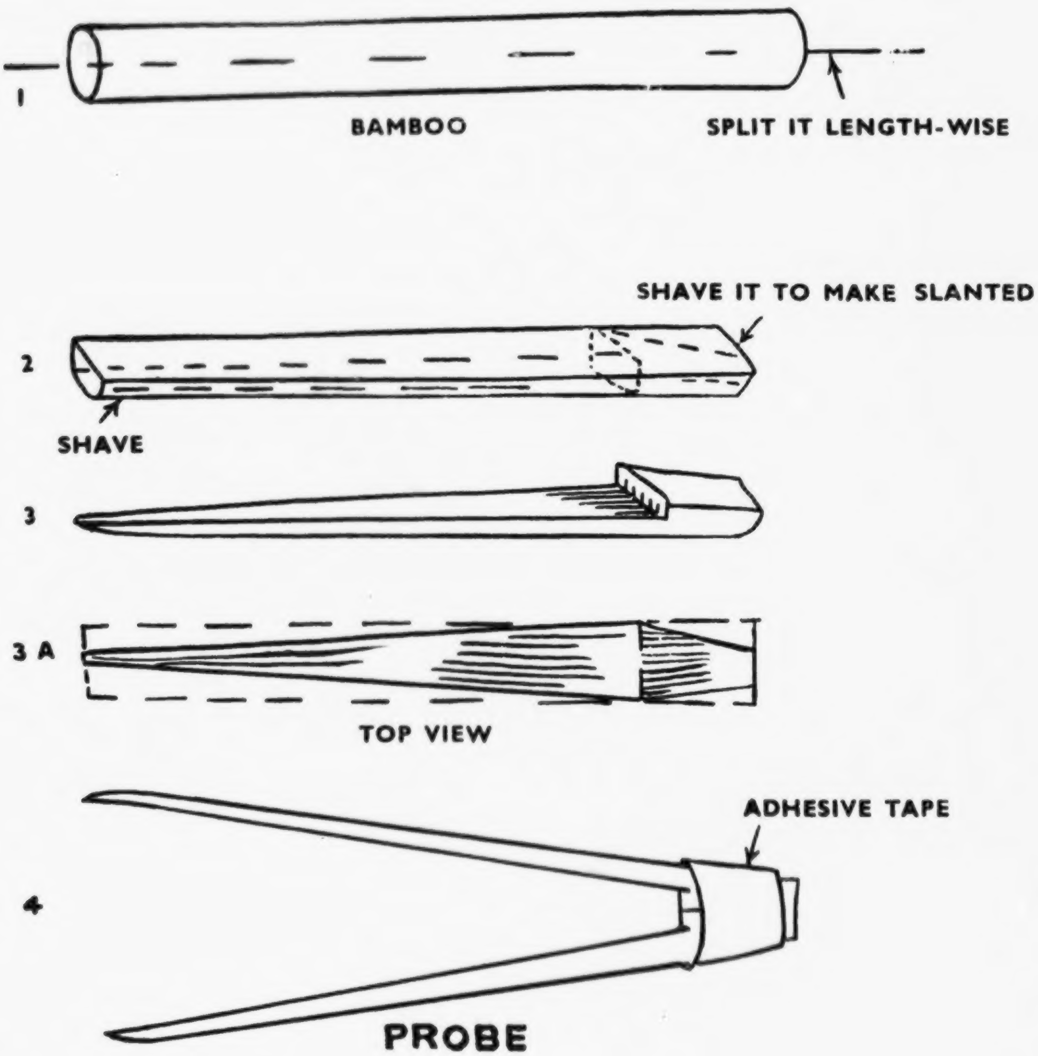
6. Shave one side of the bamboo to a thickness of about 1/8″ leaving 3/4″ off at one end unshaved. See diagram.

7. Shape the shaved portion to look like one half of a pair of forceps.

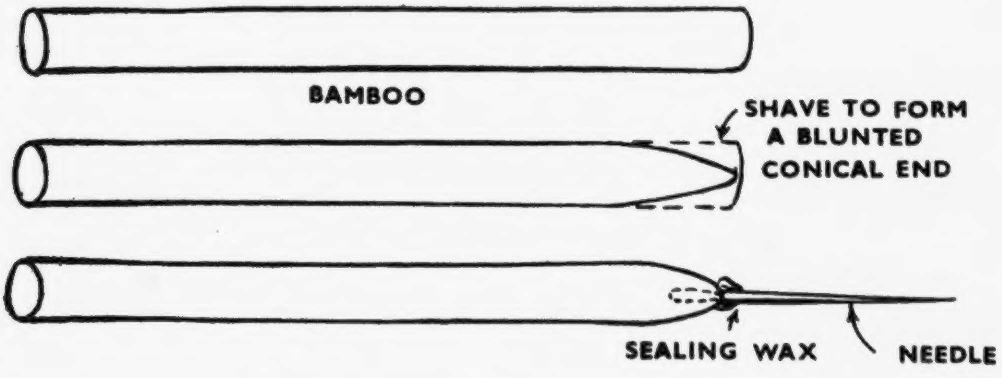
8. Shave the 3/4″ end of the bamboo, making it slope towards the unpointed end.

9. Prepare another piece just like the first.

FORCEPS

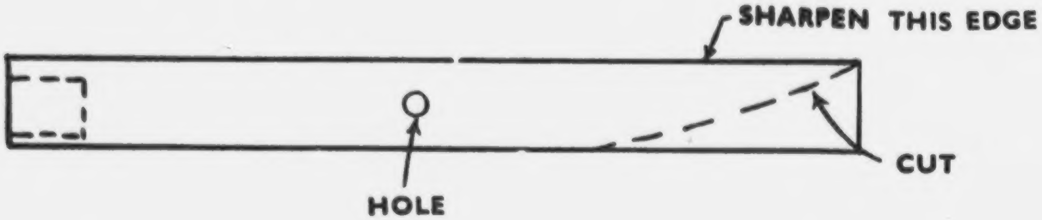

1
BAMBOO
SPLIT IT LENGTH-WISE
SHAVE IT TO MAKE SLANTED
2
SHAVE
3
3 A
TOP VIEW
ADHESIVE TAPE
4

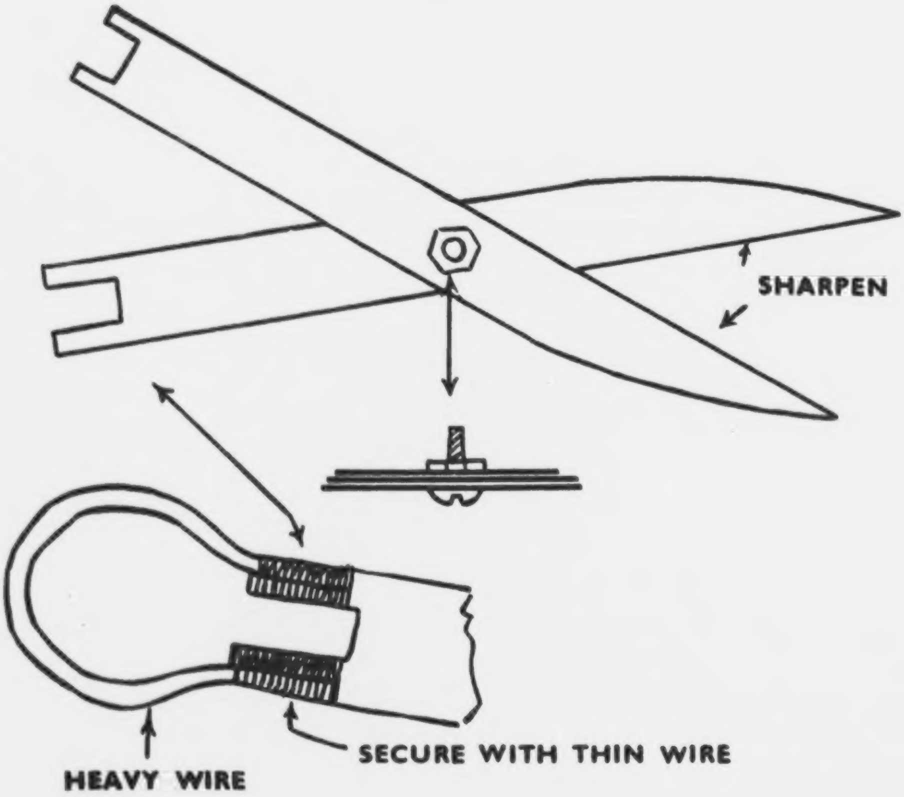
PROBE


BAMBOO
SHAVE TO FORM A BLUNTED CONICAL END
SEALING WAX
NEEDLE

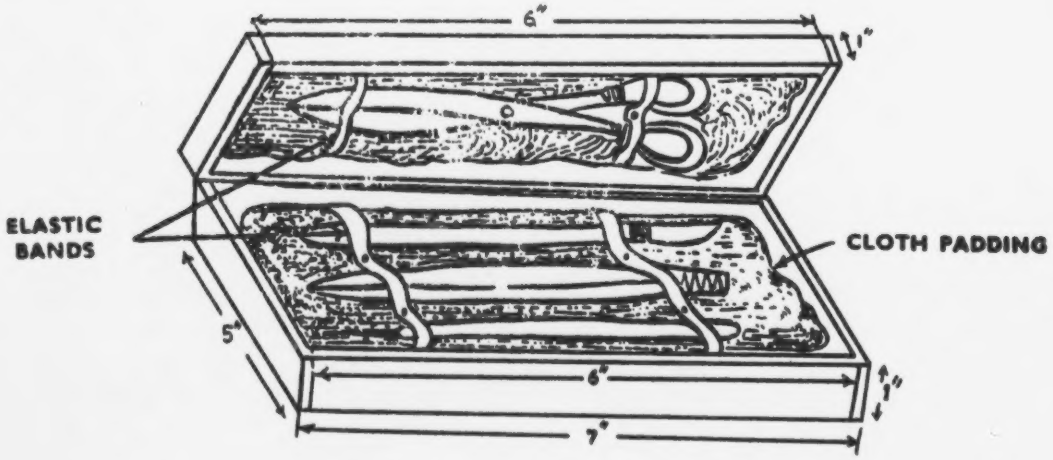
SCISSORS

STRAPPING
(TWO PIECES ARE REQUIRED)

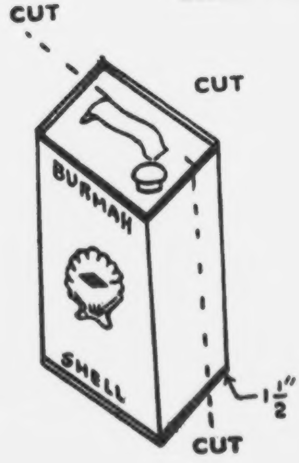

SHARPEN THIS EDGE
CUT
HOLE

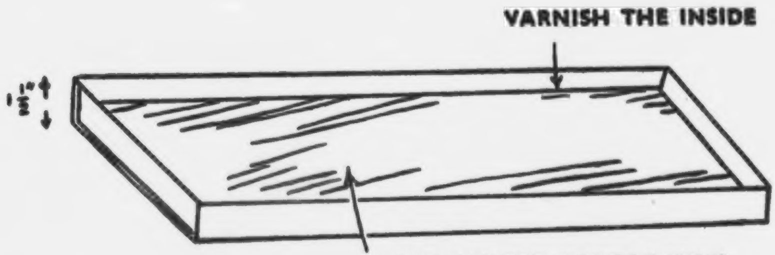

SHARPEN
SECURE WITH THIN WIRE
HEAVY WIRE

THE BOX


6"
1"
ELASTIC BANDS
CLOTH PADDING
5"
6"
1"
7"

DISSECTING PAN


CUT
CUT
BURMAH
SHELL
$1\frac{1}{2}$"
CUT


VARNISH THE INSIDE
$1\frac{1}{2}$"
POUR MELTED CANDLE WAX
OR PARAFFIN WAX $\frac{1}{2}$" THICK

10. Put the thick ends together and tie them with strong thread. Wrap some adhesive plaster around the thick ends.

11 *Dissecting Needle* : Take a bamboo piece about 5" long and 3/8" in diameter.

12. Shave one end to form a conical part. The end of the conical part is to be blunt.

13. Make a hole about 1/4" deep in the blunt end.

14. Take a needle and with the help of pliers force the blunt end of the needle into the hole. Secure it in the hole with sealing wax.

15. *Scissors*: Take two pieces of strapping 1/2" wide and 6" long.

16. Make holes at the geometrical centre of the two pieces.

17. Shape them as shown in the diagram.

18. Bolt the two pieces together.

19. Bend 2½" to 3" of heavy wire to the shape shown in the diagram. Secure it to the ends of the scissors with thread and adhesive tape.

20. *Dissecting Pan* : Cut the 3 litre tin as shown in the diagram to form a tray 1½" deep.

21. Melt some candle wax and pour enough into the tray to form a layer 1/2" deep.

22. Varnish the exposed metal.

23. *Box Container for Kit* : Assemble the wood pieces as shown in the diagram.

24. Varnish them.

25. Attach the top to the box with hinges.

26. Put cloth padding inside.

27. Fix elastic bands inside the bottom and top parts as shown in the diagram.

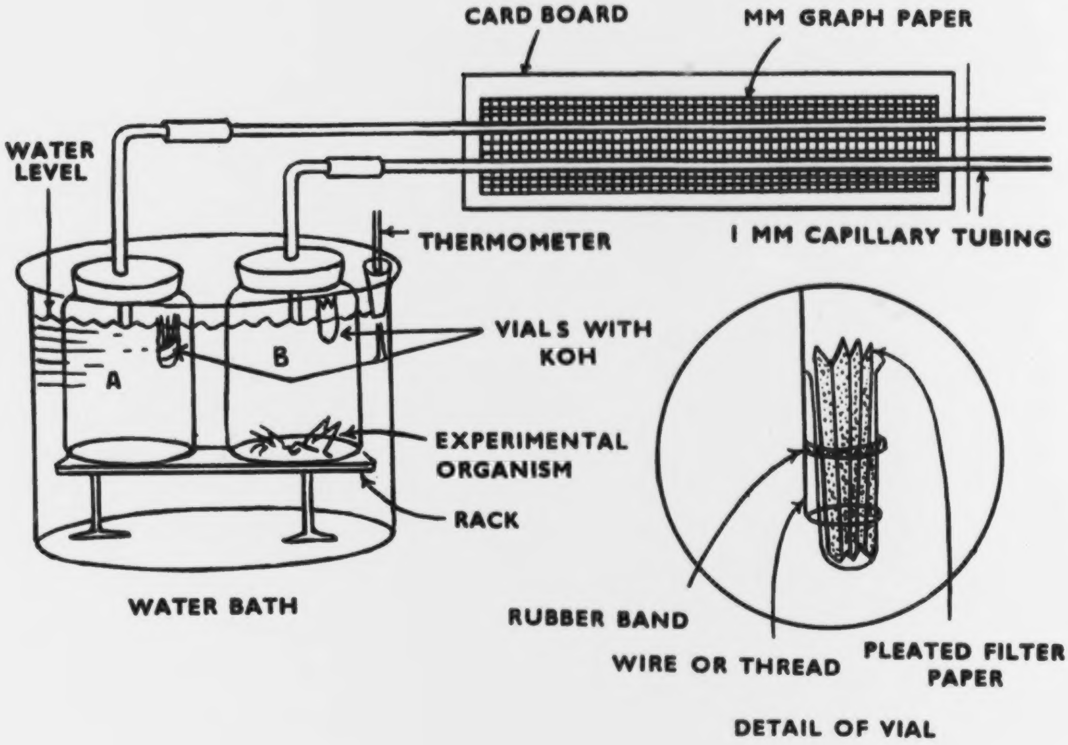
28. Adjust to fit your dissecting tools.

Uses in practicals and demonstrations

This piece of apparatus is an emergency measure for biology classes where dissection by the entire class is advisable but the materials are not available.

With this kit the student can be expected to have a kit with which he can perform dissections in the classroom, at home or in the science club.

RESPIROMETER


CARD BOARD
MM GRAPH PAPER
WATER LEVEL
THERMOMETER
I MM CAPILLARY TUBING
VIALS WITH KOH
A
B
EXPERIMENTAL ORGANISM
RACK
WATER BATH
RUBBER BAND
WIRE OR THREAD
PLEATED FILTER PAPER
DETAIL OF VIAL

RESPIROMETER

Materials required for construction

1. Any large tin or glass container.
2. Two wide mouth bottles.
3. Two one-holed rubber stoppers.
4. 12" of 5 mm glass tubing.
5. Two 3" pieces of capillary tubing
6. Rubber tubing.
7. 24 gauge iron wire.
8. Rubber bands.
9. Medicine dropper.
10. Graph paper.
11. 6" × 36" cardboard piece.
12. 15% solution of KOH or 40% solution of NaOH.
13. Filter paper.
14. Two small test tubes or injection bottles.
15. One small wooden stand
16. One thermometer.
17. One cork.

Procedure for construction

1. Cut the 5 mm glass tubing into two 6" pieces and bend each 2" from one end to form a 90° angle.

2. Connect the 2" end of each glass tube to the capillary tubes by using a small piece of rubber tubing.

3. Fit the long ends of the 5 mm tubing to each of the one–holed stoppers.

4. Pleat two pieces of filter paper and dip them into the KOH soulution. Put them into the small test tubes or the injection bottles. See diagram.

5. From the iron wire make a loop which fits the necks of the test tubes. Bend the rest of the wire upwards and into a hook which you will attach to the lip of the wide mouth bottles. Wrap a rubber band around the bottle to secure the wire to the side of the test tube. The test tubes should now be suspended inside the wide mouth bottles.

6. Close the wide mouth bottles with the rubber stoppers mentioned in step 3 above.

7. Attach the graph paper to the cardboard piece and then fix this piece behind the capillary tubes. See diagram.

8. Place the stand in the large container and put the two wide mouth bottles on it. Secure in place with rubber bands.

9. Pour water into the large container until it comes to the necks of the bottles.

10. Fix a thermometer in a cork and float it in the water.

11. Put a small cockroach or any other insect, whose respiration you wish to measure, in one of the wide mouth bottles.

12. Introduce a drop of colored water into the capillary tubes and the apparatus is ready for your experiment.

Uses in practicals and demonstrations

This piece will be found helpful in measuring the rate of respiration in living organisms, either in your science club projects or in your classroom demonstrations.

STEPS IN BUILDING SCIENCE APPARATUS

1. Read the plans (or draw up a set of plans). Take special note of the types and sizes of materials required and modify the plans if necessary to suit your needs. For instance, if certain materials are not available, you may substitute other materials in their place Most important, thoroughly understand the plans or directions before beginning the construction. It is difficult and often unsatisfactory to correct construction mistakes which result from poorly understood directions.

2. If wood is to be used, select a type that is easy to work with; measure and mark–off the sizes required. Cut the pieces, making sure that they square, and use sandpaper to make them smooth Such operations as chiseling and boring holes should be done during this step.

3. Fasten the sanded pieces of wood together with nails, screws, bolts or glue as specified in the plans. Proceed to step four before adding any other materials to the apparatus.

4. Apply the first coat of varnish and allow the assembly to dry. (Refer to the technique headed "How to Varnish.") After the first coat of varnish has dried, sand lightly with a piece of fine grade sandpaper and apply the second coat of varnish, which should dry to a glossy finish. Set the piece aside and wait until it is completely dry. If it is handled while the varnish is wet or tacky, the finished surface will be marred.

5. The time required for the varnish to dry need not be wasted. During this time you can make the metal, plastic and glass pieces required for the apparatus. Follow the plans carefully in this regard so that these pieces will fit into place properly.

6. Assemble the apparatus as shown in the plans.

7. Calibrate the scales, if needed. Test the apparatus for precision, and repair the parts that are not working adequately. This step is the most important. The following are some common mistakes which you should recheck:

a. Excess friction may be caused by sticky varnish or rust.

b. Electric current will not flow through metal terminals which are coated with varnish or rust.

c. For a balance arm to operate properly, the fulcrum must be above the centre of gravity of the arm.

LIST OF MATERIALS THAT ARE USEFUL FOR THE ACTIVITIES SUGGESTED IN THIS BOOK

1. Empty tin cans of various sizes.
2. Medicine bottles with rubber stoppers – like the penicillin injector bottle.
3. Empty injection vials.
4. Steel needles of different sizes.
5. Press buttons.
6. Empty bottles of different sizes.
7. Blown out light bulbs.
8. Blown out fluorescent tubes.
9. Soda bottle lids.
10. Horlicks bottles and any wide mouthed bottles.
11. Bamboo pieces.
12. Blown out pen torch bulbs.
13. Strapping.
14. Card boards from old cutnote books, empty cardboard boxes and the like.
15. Heavy wire pieces.
16. Copper wire from old dynamos, motors or transformers.
17. Corks.
18. Old injection syringes.
19. Wood from package boxes.
20. Old torch light cells.
21. Old razor blades.
22. Cigarette packs with cellophane paper and aluminium foil.
23. Metal strapping from deal wood crates.

List of materials that are easily available

1. Bolt and nuts.
2. Washers.
3. Nails.
4. Glass tumblers.
5. Rubber bands.
6. Paper clips.
7. Adhesive tape.
8. Soda straws.
9. Wooden foot scale.
10. Pitch.
11. Plane mirrors.
12. Polyethyline tubing.
13. Rubber tubing.
14. Metal or plastic funnels.
15. Medicine measures marked in millilitres.
16. Radio aluminium pulleys.
17. Earthernware pots.
18. Enamelled basin etc.
19. Pad clips.
20. Cloth pins.
21. Graph paper.
22. Press buttons.
23. Glue.
24. Toroh cells.
25. Quick fix.
26. Iron rods.

List of chemicals that are available in the ordinary market or medicine stores

1. Spirit.
2. Silver nitrate.
3. Potassium permanganate.
4. Soda bicarbonate.
5. Potassium carbonate.
6. Sodium carbonate.

7. Yeast tablets.
8. Sodium hydroxide.
9. Slaked lime.
10. Chalk.
11. Sulphuric acid dilute - petrol stand.
12. Vaseline.
13. Lead metal.
14. Potassium chloride.
15. Potassium nitrate.
16. Carbolic acid (phenol).
17. Magnesium sulphate.
18. Dyes.
19. Glycerine.
20. Sodium chloride.
21. Ammonium chloride.
22. Copper sulphate.
23. Alum.
24. Turpentine.
25. Gasoline.
26. Sodium thiosulphate.
27. Iodine.
28. Bleaching powder.
29. Sealing wax.
30. Candles.
31. Cane sugar.
32. Borax.
33. Boric acid.
34. Sulphur.
35. Aluminium.
36. Iron filings.
37. Magnesium ribbon.
38. Mercuric oxide.
39. Lead oxide.
40. Zinc oxide.
41. Ferrous sulphate.
42. Potassium iodide.
43. Oxalic acid.
44. Camphor.
45 Napthalene.
46. Menthol.
47. Indigo.

—:o:—

Chapter 6

TOOLS USE AND CARE

Tools Use And Care

This chapter is designed to give you a step-by-step introduction to the basic tools and techniques needed for improvising science apparatus. Discriptions of techniques for the use and care of hand tools is given in the first part of the chapter. The second part contains instructions for using sandpaper and techniques for varnishing along with the procedure for the care, cleaning, and storing of brushes.

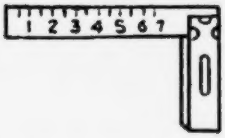
A basic set of hand tools is modest in cost, yet it represents a significant expenditure for most schools. To protect this investment it is necessary to use and care for the tools properly. Improper use or neglect of tools will result in unnecessary damage which will require repair or replacement.

The following chapter describes techniques for use and care of your tools.

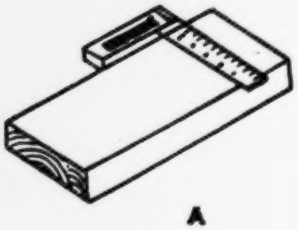
HOW TO USE

There are a few general practices common to the care of all tools. First, all tools which have a cutting edge should be kept sharp. Contrary to what you might expect, there is nothing more dangerous than a dull tool and nothing safer than a properly sharpened one.

The greatest enemy of tools in India is rust. To protect your tools the non-working surfaces should be painted. Good quality synthetic enamel is best for this purpose. The other surfaces and joints of the tools can be protected by applying a thin film of oil during day.



TRY SQUARE



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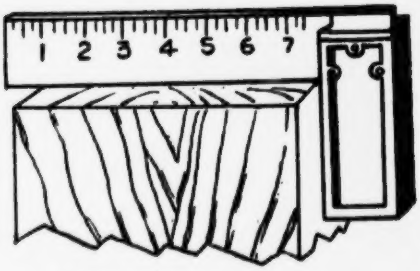

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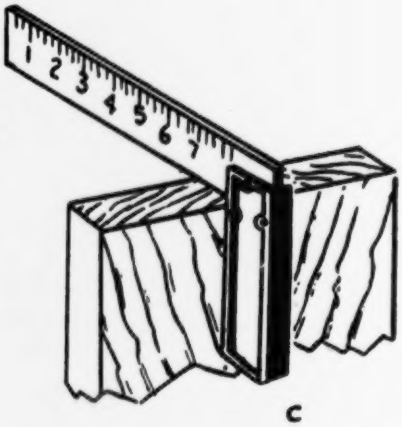
USING TRY SQUARE



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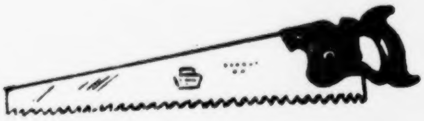
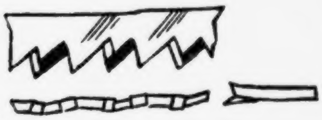
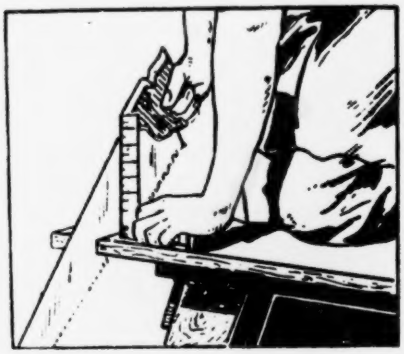


CROSS CUT SAWS





USING SAW

to day use or a layer of grease for long-term storage. Finally, moving parts should be kept oiled, free from grit and dust and the joints should not be allowed to become loose.

Tools may be divided into groups according to their intended uses. For convenience the care and use of specific tools is organized according to the following classifications:

Tools used for measuring and lay-out.

***Try-Square*:** A short steel scale is rigidly fixed to a handle at an angle of exactly 90°. The important thing to remember in caring for this tool is that the right angle must not be knocked out of alignment. This means that the square should not be dropped or used for pounding. The scale can be kept clean by polishing it with steel wool or emery cloth. A light film of oil should then be applied to protect it from rust. The try-square has four major uses:

1. It is used to draw lines perpendicular to the edge of a board.

2. It is used to try i.e. to test the squareness of a board after it has been cut.

3. It can be used as a guide while sawing to keep the saw perpendicular to the wood.

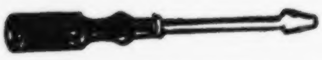
4. The scale of the try-square may be used for measuring short distances accurately.

Cutting tools for woodworking.

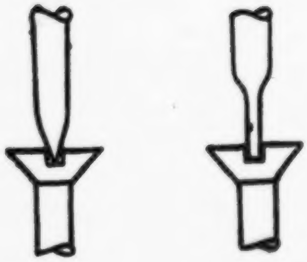
Hand Saw: An 18" saw is preferred but a 12" saw is satisfactory. The handle and blade should be joined with screws and not with rivets. Screws can be re-tightened if the blade should become loose. The saw must be kept sharp and in addition the teeth must be "set." Setting means that the teeth are alternately bent slightly to each side This makes the saw cut a wider slot or "kerf" so that the blade does not bind up or get stuck. When you buy a saw you should have it set and sharpened by a local carpenter since new saws from the shops often have not been set and sharpened. The saw blade is particularly vulnerable to rust and should be kept coated with a thin film of oil.

Before beginning to saw, draw a line with the try-square, marking the cut to be made. In sawing, an allowance must be made for the width of the "kerf." To start the saw cut, use two or three pull strokes, using the thumb or a try-square to hold the saw blade perpendicular and on the marked line. Use short strokes until the cut is well started and then continued with full length even strokes. For the best results, the saw should be held at an angle of 45° to the wood. The picture shows a workman holding a board on a low bench with his knee. Sawing may also be done on a work table or with the board clamped in a vise. If the saw is sharp and properly set, it will do the work easily. There is no need to press hard. Use long even strokes and let the saw cut by its own weight.

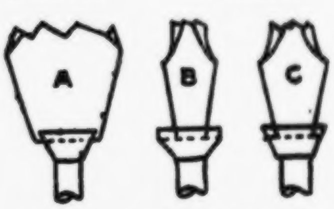
Wood Rasp: A machine made wood rasp is far superior to one which is hand-forged. The 8" size is most useful in the science workshop. A machine-cut rasp can easily be recognized by the eveness of the sharp triangular teeth. A wood rasp cannot be resharpened, so it is important that it be protected from damage. As its name implies, it is for use only on wood — use on metal will ruin it. Dropping the wood rasp on the floor will also damage it. The user



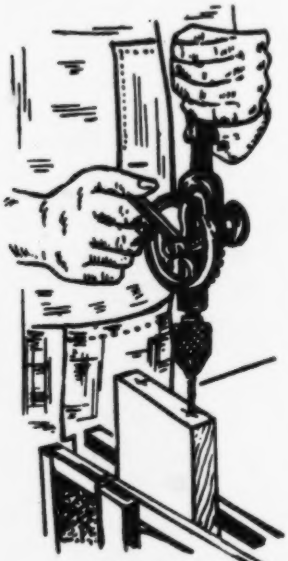
SCREW DRIVER



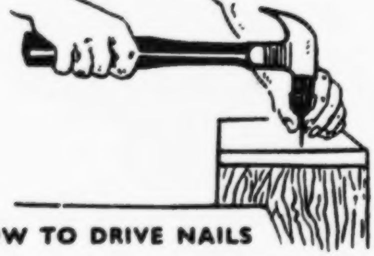
WRONG RIGHT



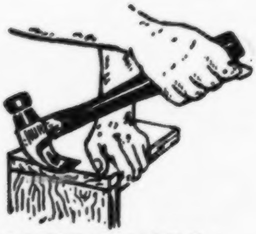
FITTING SCREW DRIVER TO SCREW HEAD



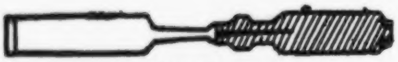
DRILLING ANCHOR HOLE



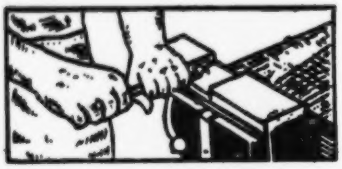
HOW TO DRIVE NAILS



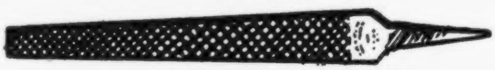
DRAWING NAILS



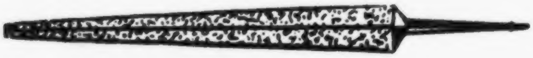
CHISEL



PARING ACROSS GRAIN



WOOD RASP



TRIANGULAR WOOD FILE

should protect his hand from the sharp pointed "tang" of the rasp by using a handle. This may be purchased or it can be made easily by drilling a hole in the end of a round piece of wood. Do not oil this tool as this will hasten the clogging of the teeth with wood particles.

The rasp may be cleaned by rubbing it with a stiff wire bush. If the rasp is to be stored, it should be wrapped in oiled paper to prevent rust.

The wood rasp is used to cut away small amounts of wood stock in squaring up a piece of wood or cutting an odd shaped piece. To use just rub it on the wood with full length strokes. Use the flat side for squaring and the round side for curved surfaces. The rasp can also be used for " counter-sinking. " This operation means enlarging the end of a drilled hole to receive the head of a screw or bolt in such a way that the head will be below the surface of the wood. Counter-sinking is done by twisting a corner of the blunt end of the rasp in the hole until it has been widened enough to fit the head of the bolt.

The triangular file can also be used for woodworking in ways similar to those just described but it is primarily for use on metal and will be discussed later.

Wood Chisel: A 1/2" wide chisel is the most useful size. Be sure that the steel is of good quality. A handle, which is absolutely necessary for use with the chisel, may either be supplied by the dealer or made as described above. As the name implies, the wood chisel should only be used for cutting wood; use on metal will seriously damage the cutting edge. The chisel must be kept sharp. This can be done with an oilstone. If you have no oilstone available, you can take the chisel to the barber for sharpening. If the edge should become nicked or chipped, the chisel must be reground. An engineering workshop can do this for you. The chisel should be protected from rust by a thin film of oil during daily use. For storage it should be coated with grease.

There are two ways of using the chisel. The first is called " paring. " Here slivers of wood are sliced off using the hand only to push the chisel. The chisel is normally held with the beveled side toward the board for this operation. The second method is used for cutting notches and removing larger chips of wood. Here the handle of the chisel is struck with a mallet or hammer. A wooden mallet is the preferred striking tool because it will not damage the chisel handle. Normally the chisel is held with the beveled side up during his operation.

Tools for making holes

Hand Drill Machine: It is important that this tool be of the best quality because inferior machines will not stand up to hard use by a science club. The drill machine should have deep cut gear teeth and should be able to be easily taken apart for lubrication and cleaning. The "chuck" the part which holds the drill but, should be well machined and should operate smoothly. The jaws of the chuck should be even in shape to hold the drill bits firmly and should be equipped with strong springs to hold the jaws open properly.

Drill bits are made of two varieties of steel; carbon steel and high speed steel. The high speed steel bits are best because they can be used for drilling in either wood or metal. The carbon steel bits can be used for drilling in wood only – if used on metal, they will be ruined. High speed steel drill bits can be recognized by the abbreviation "HSS" stamped on the "shank" (unpointed) end of the bit. Drill bits are made in sizes which are multiples of 1/64". To start only two or three bits in common sizes such as 1/4", 3/16" and 1/8" are necessary. Other sizes may be purchased later. To protect the sharp cutting edges of the drill bit, it should not be dropped or allowed to rattle around loose in your tool box.

A holder for drill bits can be made by drilling appropriate sized holes part way through a small block of wood. If your drill bits do need sharpening, they can be re-ground at an engineering workshop. To care for the drill machine, keep it clean and make sure that the moving parts are properly lubricated.

Drilling is an obvious operation but there are some points which should be mentioned. First, the location of the hole to be drilled should be accurately measured and a "+" marked to indicate the precise centre. If the hole is being drilled in metal, a mark should be made with a nail or a centre punch to keep the point of the drill from slipping. Grasp the chuck of the drill machine in your left hand and rest the upper handle against your body. Open the jaws of the chuck by turning the crank anti-clockwise. Insert the drill bit in the chuck and tighten it in place be turning the crank clockwise. Be sure that the bit is firmly and evenly held by all three jaws so that it will not come loose while drilling. For best results, the wood or metal stock to be drilled should be firmly clamped or held down.

Don't drill directly on the table top. Place a scrap of wood under the piece to be drilled to avoid marring of the table. Sight down the drill machine or use a try-square to make sure that the drill is perpendicular to the piece being drilled. Use moderate pressure and keep turning the crank in a clockwise fashion until the hole is finished. Continue turning clockwise while removing the drill from the hole.

Before putting the drill away, remove any shaving which may be stuck in the flutes of the drill bit. The chuck should be closed during storage to prevent dust and dirt from clogging it.

Other Boring Tools: The triangular file and the rasp may be used for enlarging holes to the size required.

Tools used for joining.

Claw Hammer: This type of hammer is specified because it can be used for drawing out as well as driving nails. A hammer weighing one pound is best. A lighter hammer is not useful for general purpose work and anything much heavier is too much for your work. It should not be used for breaking rocks etc., as this will ruin the smooth striking face and spoil it for its intended uses. This tool, like all of the others, may be protected from rust by appropriate applications of paint and oil.

In use, the hammer should be grasped near the end of the handle so as to take full advantage of the leverage of the handle. For very delicate work you may find that you can guide the hammer more accurately by grasping it near the centre of the handle. Hold the nail between the fingers and start it with light taps of the hammer. After it is started drive it in with firm, smooth strokes. The claw hammer can also be used for drawing out nails as shown in the picture. If a nail starts to bend while it is being driven, it should be removed and new one started.

Screw Driver: This tool should only be used for turning screws and bolts. It will be ruined if it is used for chipping or prying. As usual, it should be protected from rust by paint and oil. If the screwdriver is to work well the tip must be kept square and of the proper shown in the diagrams. When the tip becomes dull and rounded it will be difficult to keep it in the screw slot. A screwdriver can be re-ground at an engineering workshop.

Before a screw is used it is necessary to drill an appropriate size starting hole. Start the screw with your fingers and turn it down with the screw driver. The screw driver may also be used for turning or holding bolts which have slotted heads.

Tools for metal working.

Tin Cutter: The proper name for this tool is "metal cutting shears," but tin cutter is more commonly used. The most vulnerable point on the tin cutter is the rivetted joint. Care must be taken that this does not become loose. This care involves such things as not cutting heavy or thick metal and not dropping the tin cutter, which could ruin the alignment of the blades. If the blades become dull they can be sharpened at the engineering workshop. As with all tools, the tin cutter should be protected from rust by paint and oil. Keep the joint oiled.

Before cutting, the line of the cut should be scribed on the metal with a sharpened nail. The tin cutter may also be used for cutting materials which are too heavy for ordinary scissors.

Cutting Pliers: This tool is used for cutting wire and bending wire and metal pieces. Like all of the tools, it must be protected from rust by paint and oil. Be sure to keep the joint oiled so that it will move freely.

There are two ways of cutting wire with the pliers. The cutting jaws are only for cutting copper wire. To cut heavy or hard wire, use the slots on the sides of the joint. The pliers will be damaged if an attempt is made to cut heavy wire in the cutting jaws. Under no circumstances should the pliers be used to cut steel sewing needles since they are made of very hard steel — attempts to cut them will cause serious damage to the pliers' cutting edge. The plier, can also be used for tightening nuts and bolts. Despite the heavy appearance of the pliers, it should not be used for pounding nails etc. Such misuse will ruin it.

Long Nose Pliers: The same precautions mentioned with regard to the cutting pliers apply to this tool, only more care is required to prevent damage. The long nose pliers should be used only for bending light gauge wire. When small nails or tacks to be hammered cannot be held in place with the fingers, the long nose pliers may be used to hold them.

Triangular File: This tool has many uses in building science apparatus. Generally it should be used with a handle like the rasp. The file should be cleaned with a stiff wire bush and should be protected from rust by wrapping it in oiled paper.

It is used mostly for either sharpening or dulling the metal of edges of metal pieces. It is also useful for scratching glass tubing or bottle so that can be cut. Also a broken off piece of a triangular file can be used for making holes in bottles as described earlier in this book.

Tools which can be purchased to supplement the basic set (list in order of preferences)

1. C-clamp (G-clamp).
2. Extra drill bits to use with drill machine.
3. Bit brace and augar bits for boring larger holes.
4. Coping saw for making fine cuts (fret saw).
5. Hacksaw for cutting metal.

Extra tools which can be improvised.

1. Centre punch — from a large nail.
2. Drill bits — cut the heads off various size nails.

TOOL TECHNIQUES

Using sandpaper

While it is possible to use almost any kind of wood to build your apparatus, the finished pieces will look much nicer if the wood is sanded before assembly. Wood which comes from the saw mill or is taken from boxes is very rough and it can be planed smooth by a carpenter before it is used.

After the pieces of wood for the apparatus have been cut to size, they should be further smoothed with sandpaper. For sanding flat surfaces a "sanding block" should be used. This is merely a small piece of scrap wood about 1" × 2" × 3" on which the sandpaper is held. For working on curved surfaces, rounded blocks can also be made. When using the sandpaper, rub it firmly along the entire length of the wood piece. Be sure to push it in a direction parallel to the "grain" of the wood —otherwise small scratches across the grain lines will result. In order to keep the woodpiece square, be careful not to sand too much.

First sand with a fairly coarse grade sandpaper, Grit No.40, then use a medium rough grade, Grit No.60. For sanding after the first coat of varnish, use a very fine grade sandpaper, Grit No.120. Emery cloth, which is used for polishing metal and for smoothing the sharp edges of cut bottles, should also be purchased in the bazaar at the same time as the sandpaper. Grit No.50 is best for multi-purpose use.

How to varnish

Proper varnishing techniques are very important when you construct apparatus made of wood. By applying this finishing touch to a piece apparatus, you give the wooden surfaces a clear and durable coating which protects the wood and gives the piece a finished look.

It is very important to use only the best quality materials in the finishing process. The only varnish which is suitable for your use is marked "Fine Quality Copal Varnish." In addition high quality turpentine should be used for thinning purposes.

Generally you should use at least two coats of varnish on your apparatus For the first coat, mix equal quantities of varnish and turpentine. When this solution is applied to the wood, it will soak in and seal the wood, protecting it from warping. For the second and succeeding coats, if desired, pure varnish should be used. The second coat seals the surface of the wood and dries to a smooth, glossy finish which will improve the appearance of your apparatus.

Steps in applying varnish

1. Prepare the wood surface by sanding with the grain until all of the nicks, scares, and scratches are removed. Clean the grease and dust from the wood by wiping with a slightly dampened cloth.

2. Dip only the tip of the brush into the tin containing the varnish mixture for the first coat Then remove the excess varnish from the brush by drawing it across the inside edge of the tin, allowing the excess to drip back into the tin.

3. Apply the varnish with long smoot strokes, using the tips of the bristles. This will help to ensure that you finished work will have an even coat. Do not "scrub" with the side of the brush.

4. Allow the first coat to dry thoroughly then sand lightly with very fine sandpaper.

5. Apply the second coat, (pure varnish) and allow it to dry thoroughly before touching or handling the apparatus in any way. This usually takes from twelve to twenty-four hours. When the varnish is dry you can proceed with further assembly of your apparatus. Be careful not to mar the smooth surface.

Procedure for cleaning and storing brushes

1. Use a proper solvent such as turpentine or paint thinner. Fill two tins with enough of this solvent so that the bristles of the brush can be completely submerged.

2. Place your brush in the first tin and swish it around for about a minute. Wipe the brush on some old newspaper and then repeat this operation.

3. Now wash your brush in the second tin to remove any remaining varnish. Dry it with newspaper and repeat the process.

4. Press the bristles into the proper shape and wrap the brush in newspaper for storage.

5 The used turpentine can be saved for further use if it is stored in press top tins. These can be the same ones used for washing or separate containers may be used.

Laboratory Techniques

Science is not "chalk talk"; it is an experience in searching for meaning. The fruits of science are developed in the deed. Brain and muscle, mind and hand are in constant collaboration.

Teaching is a personal invention. Each teacher will have his own ways of using a great variety of techniques. All the individual procedures and the patterns in which they are used, and their variations, which different teachers found practicable, cannot be included in one book.

The technique, and procedure, the device, whatever it is, fits within a pattern, the curricular pattern. A teacher plans a unit of work. At the end of the unit the students are to have mastery of a large idea, perhaps a concept. The teacher will have to use all possible methods to help the students achieve learning a concept or an idea. Techniques should be part and parcel of the teaching development within a unit.

In a well equipped laboratory some apparatus are found not in working order or with some parts broken or missing. Such apparatus can be repaired if the teacher learns some basic lab techniques. With these views in mind the following procedures are included in this book.

General techniques

1. Black board paint.
2. Casein glue.
3. Waterproofing glue.
4. Impervious corks.
5. Ink to write on glass.
6. Adhesive for joining glass to metal.
7. Aquarium cement.
8. Washing of glassware.
9. Removing grease and tar from glassware.

Glass work

A. Glass tubing.

1. Cutting tubing.
2. Cutting tubes of large diameter.

3. Bending tubing.
4. Fusing tubes of same diameter.
5. Joining tubes of different diameter.
6 Preparing nozzle tubes (medicine-droppers).
7. Annealing.
8. Preparing inoculators for bacteria cultures.

B. Bottles.

1. Cutting.
2. Apparatus to cut bottles.
3. Use of glass cutter.
4. Rheostat for glass cutter.
5. Drilling holes in bottles.

GENERAL TECHNIQUES

Blackboard made from paper or cloth (for village school)

The cloth or paper is first saturated with linseed oil varnish. Then, apply many coats of the following mixture :

Copal varnish	1 part
Turpentine	2 parts
Fine dry sand	1 part
Glass powder	1 part
Cround slate	2 parts
Lamp black	1 part

Casein glue

Materials :

1. Milk (goat's milk is cheaper).
2. Lemon juice or vinegar.
3. Sodium bicarbonate.

Method: Put a pint of milk into an enamel pan and add a cup of the acidic liquid. Heat and stir it until lumps form. Pour the coagulated milk into the bowl and let it cool. Separate the lump from the liquid and throw the liquid away. Then add a teaspoon of sodium bicarbonate and a cup of water. A chemical reaction takes place and an excellent glue is the result.

Waterproofing glue

Mix one crystal of potassium bichromate per ounce of glue. After drying, the glue will be waterproof.

To make corks impervious

1.	Gelatine or common glue	15 parts
2.	Glycerine	24 parts
3.	Water	500 parts

Meltthe glue in water and add gelatine

Heat the mixture to 44°–48° C. Place the corks in the mixture for several hours. Dry them in the shade.

To make them acid proof, put them in the following liquids

1.	Vaseline	2 parts
2.	Paraffin	7 parts

Heat them to about 105° F.

Ink to write on glass bottles :

1.	Shellac	20 parts
2.	Alochol	150 parts
3.	Borax	35 parts
4.	Water	250 parts
5.	Soluble dye	

Mix shellac and alcohol. Mix borax and water and then combine the solutions. Finally, add the dye to the solution.

Adhesive for joining glass to metal

A solution of sodium silicate may be used as an adhesive for joining glass and metal. A paper gasket is soked in a solution of sodium silicate and inserted between the surfaces of the glass and metal to be joined.

Aquarium cement

This type of cement will stick to metal, glass, stone, or wood. The first four ingredients should be mixed together in the dry state. Then just before using, add enough linseed oil to make a stiff putty. Allow three to four days for this cement to harden after it has been forced into crevices and smoothed over with a spatula. Use the following parts by weight :

1	Litharge	10 parts
2.	Plaster of paris	10 parts
3.	Powdered resin	1 parts
4.	Boiled linseed oil	

Washing of glassware

All glassware should be cleaned as soon as the experiment is over. If they are left with the chemicals inside, a thin film adheres to the inside of the glass containers. In many cases this cannot be removed by washing with water or soap solution. In this case the following procedure should be followed :

Take 35 ml of saturated aqueous solution of sodium or potassium dichromate and pour into it 100 ml of concentrated sulphuric acid Warm it.

This hot solution is to be poured into the glassware that is to be cleaned. Keep it overnight. Then the glassware is thoroughly rinsed with hot water until all the chemicals are removed. When water is found to completely wet the glass, the glassware is clean. If it is not clean, water collects as drops on the surface.

To remove grease and tar materials from glassware

12 grams of sodium hydroxide is dissolved in 12 ml water. Add 100 ml of 95% ethyl alcohol (rectified spirit will do). The glassware is kept in this mixture for some time and then washed under running water.

GLASS WORK

Cutting tubing

The simplest method applicable to sizes up to approximately 25 mm is to make a scratch with a triangular file at the point where the break is to occur. Do not try to saw the tube. Having scratched the tube, grasp it firmly, so that the scratch is between the hands and the thumbs are placed behind it on the tube. Bend the tubing at the scratch creating tension on the scratch side and at the same time tend to pull the tube apart. A straight clean break should result.

Cutting tubes of larger diameter

Method 1 : A scratch is made around the tube. A piece of small gauge nichrome wire is fitted around the tube over the scratch and held tightly. The ends are connected to the mains. When the current is turned on, the wire becomes dull red. After a few seconds, the current is turned off and water is applied with a brush to the heated wire. A clean break will result.

Method 2 : A scratch is made around the tube. An iron rod is heated to redness. Touch the scratch with the hot rod repeatedly, until the tube is cracked. A little skill is necessary to make a clean cut.

Bending glass

Apply the flame to the place where the glass tube is to be bent. Rotate the tubing heating all sides equally. For a "U" bend, heat a large area of the glass in this way. Remove the tubing from the flame when it starts to sag, and bend it to the desired shape, applying equal pressure with each hand. Hold the tube in one plane until it hardens. A good bend retains the same size bore through-out the bend. You can use the corner of an asbestos pad to bend the tube at right angles.

Fusing tubes of the same diameter

Connect a rubber tube to the free end of one of the glass tubes and cork the free end of the other tube. In joining tubing it is essential that both pieces be heated uniformly and equally. Hold the tubes a short distance apart correctly aligned (you can construct a wooden stand for correct alignment). The ends that are to be joined together are brought together, almost touching. When both are heated to an orange-red, remove the flame and firmly push together and immediately pull apart (for a small distance) all in a continuous motion. The tubing will be slightly thicker at the joint. Heat this junction, remove the flame and blow gently through the rubber tube to even out the glass. The joints will show bands of thick and thin glass which are readily seen by differences in colour when the flame is on, the thin portions being yellower. If the bands are in excess, they may be evened out by a combination of heating and blowing.

Joining tubes of different diameters

The bigger diameter tube is connected to the blow hose and tubes are aligned on a wooden stand. Keep the tubing a small distance apart. Heat the end of the wider tube to an orange-red colour. Remove the flame and with a carbon paddle (can be made with the carbon rods from old torch cells) touch the end of the tubing to form a conical shape. Heat the end of the narrower tube and with a pointed carbon rod flare the end so that the tapering of the bigger diameter and the flared up end of the smaller diameter tubes come up nearly to the same diameter. Now bring the tubings almost together, heat them to redness and proceed as in joining the tubes of the same diameter.

Medicine dropper

Take a glass tubing and heat the middle part of it in the flame. When the glass becomes soft, slowly pull the two ends apart. If you pull quickly the tapering may not be uniform When you get two pieces of the tubing, gently break off a small portion of the tapered end. Then heat the wider end of the tube until the glass becomes soft and press the end on an asbestos pad. By doing this you form a rim at that end of the tube. Attach a small rubber tubing or a rubber nipple used for milk bottles.

Annealing

When hot glass is allowed to cool quickly, it develops very small cracks. When you heat the same glass again it will break. But if the glass is annealed it will not crack.

The glass when removed from the flame should be kept very near the flame for sometime. Later, is slowly taken away from it. Then it is heated in a smoky (non-oxidizing) flame for sometime and is taken away slowly.

Inoculators for bacteria cultures.

Method 1 : Take a glass rod of small diameter. Heat the middle portion and when the glass becomes soft pull the rod apart. This should be done slowly. A long thread of glass will form in the middle. This glass thread can be used as an inoculator.

Method 2 : Push a thin iron wire into the bore of a capillary tube keeping about 6" of the wire outside. Heat the capillary tube at this end, until the glass melts around the wire in the bore.

CUTTING GLASS BOTTLES

For experiments in chemistry, biology, and physics, glassware is a necessity. Ordinary glass bottles can be used for most purposes, if they are cut into the required shape.

Materials required:

1. Glass cutter or triangular file.
2. Thread from gunny bags.
3. A bucket of water.
4. Kerosene and match box.

Kerosene method.

This method is useful when there is no supply of electricity and requires patience and skill. Make a scratch on the bottle with a triangular file along the line where the break is to occur and tie the thread along the scratch. Soak it with kerosene oil completely. Light the thread with a match and turn the bottle slowly so that the flames heat the scratch line evenly. The flames must not spread very far on either side of the mark. When the flame goes out, quickly dip the bottle into cool water. If the procedure is followed, a clean break will occur. Polish the cut edges with emery paper or a triangular file.

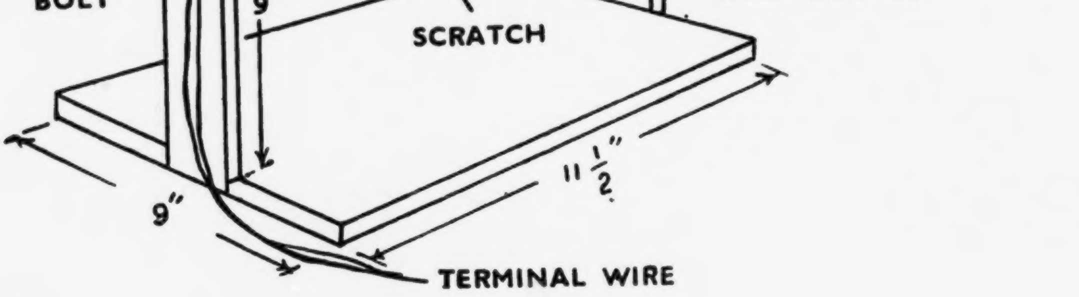
Electric method

This is useful where electricity is available. Wrap paper around the bottle so that an edge of the paper represents the line where the bottle is to be cut. If necessary, paste the paper to avoid slipping. Make a scratch on the bottle along the edge of the paper with a glass cutter. If the glass cutter is not available use the triangular file. Move the file in one direction only; don't make a to and fro movement. When the wire becomes red hot put the bottle on the wire so that the scratch touches the wire. Slowly turn the bottle after you hear a cracking sound. After a complete revolution, dip it in the bucket of water. A clean cut will be the result.

Electric glass cutter

With this glass cutter, even very thick bottles and jars may be cut evenly. The materials needed are: 2 bolts, 2 washers, wood, and 1000 watt or 24 gauge heater wire. This heater wire is sold at most electric stores. One can use the sizes of wood pieces and bolts that he likes, but you should use about 8″ of the straightened 1000 watt heater wire. When this wire is fastened with nuts to the two bolts, it should curve downward as the drawing indicates. The base piece should be notched the same way that the lever apparatus base is notched; then the upright wood pieces may be nailed in place. The washers dissipate the heat and prevent the wood from reaching kindling temperature. If you use large bolts (3/8″ × 3″) the washers may not be needed.

ELECTRIC GLASS CUTTER



Using the glass cutter

This cutter must be used with with a rheostat. The glass should first be scored or scratched evenly where it will be cut. Clean the glass inside and out around the scratch. This will help to make an even cut. After the glass is scored, turn the electricity on. Use the rheostat to adjust the current until the wire is red hot. TAKE CARE — one can receive a serious shock by touching the bolts or other metal parts of the apparatus. The glass should be dry to avoid shock. Roll the glass slowly along the hot wire touching the wire only on the scratch mark. After making a complete revolution, pour cool water on the scratch The glass should break evenly along this mark It takes a little practice to cut the glass evenly.

Note: Students should not use this cutter unless a teacher is supervising. *Disconnect the cutter when it is not being used.*

Water rheostat

The water rheostat is a variable resistor which may be used with a glass cutter (for construction see Chapter V), or any electrical device which you operate with low power alternating current. The principle of this rheostat is the conduction of electricity by electrolytes. This rheostat conducts electricity through a sodium chloride (NaCl) solution and since the solution places a large resistance in a circuit, much electrical energy is dissipated as heat, and the remaining energy may be used to activate low energy apparatus.

Drilling holes in glassware

Sometimes it would be useful to drill a hole in the side of a bottle. The following procedure is useful :

Materials : A triangular file
Turpentine.
Camphor.

Take a little turpentine in a bottle cap, Put a small amount of camphor in it. Chip off the end of the triangular file with the hammer. The chipped end has sharp corners. Dip one of these corners into the turpentine and camphor mixture and bore a hole in the bottle. Continue the process slowly, and steadily, applying a little pressure. Reduce the pressure when the glass is about to give way. The hole can be enlarged with a round file using the turpentine mixture.

BIOLOGICAL TECHNIQUES

Microscopic Techniques – Temporary Mounts

1. Temporary wet mounts
2. Preventing swelling
3. Slowing down evaporation
4. Cutting sections by hand
5. Hanging drop preparation
6. Concentrating the organisms in a culture
7. Slowing down protozoa
8. Cytoplasmic streaming

Microscopic Techniques – Stains

1. Non vital stains

2. Vital stains
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4. Onion root tip smear slide
5. Blood smears
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8. Bacterial smears
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Microscopic Techniques - Permanent Slides

1. Permanent slide techniques
2. Fixation
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4. Embedding
5. Sectioning
6. Hydration
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Chemicals for Microscopic Techniques

1. Vital stains
   - Methylene Blue
   - Neutral Red
   - Congo Red
2. Simple stains
   - Iodine stain
   - Crystal violet
   - Gram's stain
   - Safranin
   - Methyl green
   - Ethyl eosin
   - Acetocarmine
   - Basic fuchsin
   - Methyl blue
   - Delafield's hematoxylin
   - Methyl orange
3. Blood stains
   - Methyl violet
   - Wright's blood stain
   - Giemsa stain
4. Fixatives
   - Ethyl Alcohol 70% solution
   - Absolute alcohol
   - Bouin's fixative
   - Allen's fluid
   - Carl's solution
   - F.A.A. (Formaldehyde, alcohol, axetic acid)
   - Preservative for green plants
   - Zenker's fixative
   - Flemming's fixative
   - Gate's fluid
   - Kleinenberg's fixative
   - Formalin
5. Other solutions
   - Mayer's albumen
   - Bolsam (Canada balsam)
   - Methylene cellulose
   - Potassium oxalate
   - Anticoagulant for blood

Technique for Preserving Plant Parts in Plastic Cloth

Techniques to Prepare Skeletons of Leaves

Collecting and Preserving Animals

1. Collecting and examining water forms
2. Another method for collecting
3. Condensed outline of method of collecting and preserving animals
4. Collecting insects
5. Killing jars
6. Mounting insects
7. Spreading of insect wings
8. Displaying insects

Nutrient Solutions and Media

1. Knops solution for Daphnia
2. Chipman's method for Daphnia
3. Culture media for bacteria
   - Meat extract broth
   - Meat extract agar
   - Potato media
4. Culture media for Drosophila
   - Cornmeal media

    - Bannana media
    - Wheat media
5. Fertilizer for acid-loving plants

Biological Solutions

1. Solutions which test for nutrients
    - Lugol's solution–test for starch
    - Benediot's solution – test for simple sugars
    - Fehling's solutions – test for simple sugars
    - Million's reagent – test for proteins

2. Absorbers and indicators
    - Potassium pyrogallote solution – to absorb 0_2
    - Potassium hydroxide – to absorb $C0_2$
    - Cobalt chloride paper – indicator of moisture
    - Anhydrous calcium chloride – moisture absorber

3. Saline solutions
    - Ringer's solution for frog tissue
    - Ringer's solution for mammalian tissue
    - Physiological saline solution for cold blooded animals
    - Physiological saline solution for warm blooded animals
    - Buffer solution
    - Hayem's solution
4. Some solutions for the stockroom
    - Acid starch solution
    - Starch paste
    - Sucrose solution
    - Stop cock lubricant
    - Lime water
    - Rennin solution

Models

1. Imitation of a living cell
2. Modelling wax for biology specimens
3. Modelling clay

MICROSCOPIC TECHNIQUES

Temporary wet mounts

A wet mount is a specimen of a slide in a drop of fluid (water, salt solution or stain) prepared for examination under low and high power. Since the fluid will evaporate, the mount is temporary. Clean both sides of a glass slide and a coverslip. Be careful not to break the coverslip. Place a drop of water in the centre of the slide. Put a small item (piece of onion skin, elodea, leaf, hair, or drop of pond water) in the drop of water. Add more water to cover the item if necessary. Then put the coverslip on the drop. The best method for placing the coverslip is to hold the coverslip at approximately a 45° angle to the slide and gently lower it with a pin until it covers the water. Bubbles may be removed by a gentle tap on the coverslip with the dull end of a pencil. Excess water can be removed from the slide by touching one edge of the coverslip with filter or ink blotter paper. The water is absorbed by the paper. You now have prepared a wet mount or water mount. It will last for a few hours.

To prevent swelling

Cells which have a fairly high salt concentration may swell when mounted in tap or aquarium water. This swelling can be prevented by putting the cells in 0.7 percent solution of salt (sodium chloride); then, add a coverslip. The salt solution must not be so strong or concentrated that the cell loses water and shrinks.

To slow down evaporation

To make the slides last for a longer period of time vaseline, petroleum jelly or candle wax may be applied around the coverslip to slow down evaporation. One method to do this is to dip the mouth of a test tube into vaseline or petroleum jelly. Apply this circle of vaseline around the drop of material on the slide and place a coverslip so that its edges are sealed to the side.

Cutting sections by hand

Most tissues are not rigid enough (even if they are fixed) to slice into thin sections without embedding them in paraffin. But some plant leaves and woody stems can be inserted in between lengths of fresh carrots and then cut with a microtome or by hand with a razor blade.

Slice a length of carrot in half. Place the item to be cut in between the two halves. Wrap this bundle together tightly and soak them in water for a few hours. The pith and enclosed tissue specimen will expand and become rigid. The material then may be sliced. with a razor blade into thin sections. The blade should be held at a small angle to the surface of the specimen. Keep the specimen and razor wet. Float the sections on water so that they will not curl. Float only the good and uniformly thin sections on to a slide and cover with a coverslip. Staining is optional.

Hanging-drop preparation

If a drop of water were examined under a microscope, light would be reflected in several directions. To avoid this we flatten out the drop with a coverslip. However in doing so, we reduce the organism's mobility or even crush them by the weight of the coverslip. A hanging drop preparation enables students to study mobility especially in bacteria, fission in protozoa, germination of pollen grains and similar phenomena. Use a clean slide and coversilp so that the surface tension of the water is not reduced. Cut a "washer", a circle with a large hole in it, out of thick cardboard. The size of the hole should be just smaller than the size of the coverslip. Apply some vaseline to both sides of the cardbord washer. Press it on to the slide. Place drop of culture medium on the coverslip. Place the inverted slide and washer over the coverslip so that the rim of the coverslip and washer are sealed by the vaseline. Quickly invert the whole preparation. The drop of medium should now be hanging from the coverslip.

If a hanging drop is not necessary, but still you do not want to crush a small item, the coverslip can be raised quite easily. Pieces of broken overslips (or for larger items, broken glass slices) can be placed on the slide around the item so that the coverslip will rest on the glass. Enough water or medium should be added to fill the space between the glass slide and coverslip.

Concentrating the organisms in a culture

Many students will want to examine protozoa, flagellates and other motile organisms. At times, the culture may be too diluted, that is, there are only a few organisms in the culture which result in only a small number of specimens being picked up in a drop of fluid for a temporary slide. Students can increase the number of organisms by pouring a portion of the culture into a long vial or test tube, and covering all but the top fourth of the tube with carbon paper, or prepare a short length of glass tubing. Insert it into a one hole stopper in a vial filled with culture, and cover the vial with carbon paper. The protozoa concentrate in the uncovered portions (the tops of the test tube or the tubing in the stoppers since most of them are positively phototropic or negatively geotropic, or gather where the concentration of oxygen is greatest at the surface). By using a medicine dropper, large numbers of organisms can be placed on a slide in one drop of media.

Slowing down protozoa

Protozoa, especially the ciliated forms, move too rapidly for high school students, especially beginners, to follow under the microscope. There are several ways to slow down the motion of ciliates for close careful study.

One way is to simply prepare several slides ahead of time and let the fluid evaporate. As evaporation continues, the weight of of the coverslip is enough to slow down the organisms.

A ring of methyl cellulose or gelatin solution can be placed on the slide and in the ring a drop of culture medium is added. The coverslip is put over the mixture. As the methyl cellulose diffuses toward the centre of the drop, the protozoa will slow down.

Cytoplasmic streaming (cyclosis)

Cytoplasmic streaming around a cell can be seen in many living cells mounted in salt solution or aquarium water. Often chloroplasts in green plant cells move around the border of a cell. Many aquatic plants illustrate this circulation of cytoplasm called cyclosis. Mount a leaf of elodea (*Anacharis*), *Nitella*, *Chara*, or *Vollisneria* on a clean slide. In elodea, use the growing tips and focus on the midrib cells. In *Nitella* and *Chara*, focus especially on the internodal cells. Keep the uppermost layer of cells facing upward on the slide. Place the leaves in warm water or bring a warming light near the container to stimulate cyclosis. The rate of streaming may be from 3 to 15 cm per hour and as high as 45 cm per hour at a temperature around 30°C.

In *Nitella* there are many nuclei in the internodes, and they also move. However, the chloroplasts are fixed within the inner surface of the cell walls and therefore do not move.

Cytoloplasmic streaming may be found in other living material. Mount mycerium threads of the bread mold *Mucor* in water or glycerine. Cytoplasma may be seen to be streaming up one side and down the other side of the thread.

Unicellular hairs on the roots of *Tradescantia* seedlings or the staminate hairs in the flower also demonstrate cyclosis very well. Mount the filament of the stamen, which has several hairs attached, in water on a slide. Granules may be seen moving from the strands around the nucleus along the wall to another strand leading to the nucleus.

The epidermis stripped off one of the inner scales of an onion will also demonstrate cyclosis when mounted unstained in water.

In amoeba, streaming can also be studied with ease. Mount a drop of the culture solution on a clean slide. Add some broken glass coverslip pieces to support the coverslip. This is done so that the specimens will not be crushed. Many vacuoles and the actively streaming cytoplasm which changes from sol to gel will be seen.

SIMPLE STAINING TECHNIQUES FOR TEMPORARY MOUNTS

Non vital stains

Lugol's iodine, crystal violet, and Gram's stain color particular structures of the cell. During this staining process some proteins are denatured and the cell dies immediately. Living cells cannot be studied with these non vital stains.

Vital stains

There may be many times when stained living cells are needed to bring out specific details of cell structure. Vital stains kill the organisms slowly. The organisms absorb these stains and continue to carry on their life functions for sometime. Thus, living cell may be stained to show cilia, flagella or stuctures within the cells. These, vital stains are methylene blue, neutral red and congo red. The methods for preparing these vital stains are listed are under the section "Microscopic Technique–Stains".

The methods for vital and non vital stains are the same. The staining techniques listed here are used for temporary mounts. Most materials can effectively be stained by these methods. Materials commonly used are onion plant and skin cells, human cheek epidermal cells, animal tissue, blood slides and cultures of protozoa and algae.

Staining techniques

Place a drop of the stain on a clean slide and let it dry as a uniform film on the slide. You can prepare several slides of these dried films of stains and keep them stored in a clean box. When they are to be used, just add a drop of protozoa culture, bacteria, yeast culture, or tissue cells on a slide. Add the coverslip. The stain will dissolve slowly into the drop of material on the slide. When making the wet mount, add a drop of stain on top of the specimen or culture medium drop on the slide. Then add the coverslip. Hold coverslip at approximately a 45° angle to the slide and gently lower it with a pin until it covers the water. Bubbles may be removed by a gentle tap on the coverslip with the dull end of a pencil. Another method to prepare a temporary wet mount (cultures of protozoa and algae cannot be stained by this method), is to place one drop of stain at one edge of a coverslip, then, draw the stain under the coverslip by absorbing the water with a piece of filter paper from the opposite side of the coverslip. The stain will diffuse into the material.

An iodine stain will stain the nucleus brown and the cytoplasm very lightly brown. Methylene blues will color the nucleus blue and cytoplasm light blue. If the stain is not dark enough, another drop of stain can be added in the same manner. The object can be lightened by adding water instead of the stain to dilute the stain.

Onion root tip smears

This is an easy method for preparing slides that are helpful in explaining mitosis. The dividing cells in which chromosomes are present can be easily found on a slide made in the following manner.

Place an onion bulb in some water for a day or two until young white roots develop on the bulb. With a razor, cut off about the last centimeter of root tip. Drop the root in a beaker containing 1N HCl for three minutes only. Then remove the root tip and place it on a slide with several drops of acetocarmine stain for several minutes. Do not allow the root tip to dry out. Carefully cut-off the deeply colored portion of the root. Discard the rest of the material. Cut this remaining portion into pieces the size of a pin head with your razor. Quickly place the coverslip over the material. Cover the slide and cover slip with a piece of paper. Carefully press uniformly on the coverslip to squash the cells; do not twist the coverslip. Remove the paper and examine the cells. If you seal the edge of the slide with candle wax, the slide may last for 15 days.

Blood smears

Blood smear is a technique to prepare permanent or semi-permanent slides of blood. Fresh blood from a finger or animal should be used. If blood is brought from the butcher, 0.1 gm of potassium or sodium oxalate should be added to every 100 ml of blood. This will prevent the blood from clotting. Place a drop of blood directly on one end of a very clean glass slide. Chemically clean glassware is a requirement in preparing blood smears. Slides can be cleaned in 95% alcohol and flamed over a spirit lamp. Place a second slide with one end at a 30° angle to the first slide. Bring the upper slide up to the drop of blood until the blood spreads uniformly along the narrow end of the slide. Push the top slide rapidly toward the opposite end of the first slide in order to form a thin film. The greater the angle between the two slides, the thicker the film will be. Let the slide dry in open air.

Wright's blood stain technique

Using Wright's blood stain is a quick easy method of preparing a blood smear which will enable you to distinguish the different types of white blood cells. Use a slide with a blood smear on it.

Place the slide on top of a dish. This will stop the excess stain from touching or remaining on the lower surface of the slide. Cover the dry blood film completely with Wright's stain for 1 to 3 minutes. This fixes the blood cells to the slide. Then add distilled water to the slide drop by drop until the stain is diluted by one half and a metallic greenish scum forms on the surface of the slide. Let this solution remain on the slide for 2 to 3 minutes. Then wash it off with distilled water; wash two or three times. Now examine the slide under a microscope; the granules in the basophils should stain deep blue, the eosinophils bright red and in the neutrophils, lilac. If the slide is too dark, it can be decolorized by washing with more distilled water.

Giemsa stain

Giemsa stain is used for both blood smears and bacterial smears.

The stock solution should be diluted by one part in ten parts of distilled water.

Use an air-dried blood smear and fix the film to the slide by placing it in 70% methyl alcohol for three to five minutes. Dry the slide in air. Then place the slide in a dish or jar (Coplin's jar if you have it) containing dilute Giemsa stain for 15 to 30 minutes Finally wash the slide in distilled water and dry it.

Bacterial smears

To make bacterial smears, the bacteria must be in a liquid suspension. If the bacteria is from a solid agar or potato culture, a small colony should be transferred to 5 ml of sterile water and mixed. A small wire loop full of the suspension is placed on a clean slide. The drop should be spread around into a thin film and allowed to air-dry. When the film is dry, pass the lower surface of the slide through a bunsen burner flame three times or through a spirit lamp flame six times. The bottom of the slide should get warms not hot, to the touch. Now the bacteria are fixed to the slide and will not come off during the staining process.

Many stains (generally those that are basic aniline dyes like basic fuchsin, crystal violet, methylene blue and safranin) can be used to color the bacteria. The stain should be diluted; pour one part of the stock solution into ten parts of water. The stain should be applied for one to two minutes then washed and blotted dry. Coverslips are not necessary unless you wish to make your slides permanent. In that case add a drop of balsam when the slide is dry and then add a coverslip.

Gram's stain for bacterial smears

Gram's stain is an important method of classifying and distinguishing bacteria. Gram-positive organisms are stained violet or blue They are usually cocci (round) except the meningococci, gonococci, and catarrhalis groups. Gram negative bacteria take a pink or reddish stain. Spirilla, spirochetes, most bacilli (rods) are acid fast bacteria and many forms which produce spores are Gram-negative.

The procedure involves staining, destaining or decolorizing, and then counter staining. Gram-positive organisms do not decolorize and maintain the violet color, Gram-negative organisms lose all color of the first stain and so pick up only the red counter stain.

Take a bacterial smear that had been fixed by waving through the flame of a burner a few times and flood the slide with crystal violet stain for one minute. Pour off the stain and add Gram's stain for one minute. Wash this off with water and decolorize with 95% ethyl alcohol. Wash several times with 95% ethly alcohol until no more stain washes off. Rewash the slide in water and counterstain by flooding the slide with safranin dye for a half minute. Wash with water, dry, and examine under the microscope.

Microscopic techniques perminent slides

The general procedure for staining and mounting permanent slides is :

1 Fix tissues and harden.
2 Dehydrate through a series of alcohols.
3. Clear tissue in xylol.
4. Embed in paraffin.
5. Section with microtome.
6. Fix sections to slide.
7. Dissolve paraffin with xylol.
8. Pass through a series of alcohols to distilled water.
9. Stain, counter stain, de-stain, if necessary.
10 Dehydrate through a series of alcohols to xylol.
11. Mount in balsam.
12. Check under the microscope.

Fixation

Tissues must be placed in fixative for two reasons. One, the cells must be killed quickly and uniformly so the cell contents are preserved and closely resemble those in the living cell. The second reason is that the fixative hardens the tissue so that it can be cut into thin transparent sections.

Some fixatives must be washed out before the cells can be stained. Normally, the cells are placed in the fixative long enough to insure that all cells have been killed (48 hours for large specimens). Then the fixative is washed out, and the tissue placed in preservative until it is to be stained. Fixatives containing mercuric chloride or picric acid must washed for at least one hour in 70% alcohol. If the tissue contains potassium dichromate, the tissue must be washed in running water for at least one hour. A list of fixatives and preservatives can be found in a later section of this book.

Dehydration

Once the tissue has been fixed and the fixative has been removed, the next step is to remove the water from the tissue. This must be done gradually so that diffusion rates between alcohol and water do not distort the delicate tissues and that the paraffin will enter all the spaces normally occupied by water. This gives support to the tissue when it is being cut into thin slices.

Tissues are normally transferred from the preservative to 70% ethyl alcohol. But very delicate tissues are first washed in water and then gradually brought up to 70% alcohol through steps of one 30% and 50% alcohol. Keep the tissues in each alcohol solution for one hour. After the tissue has been in 70% alcohol for a few hours, transfer it to 95% alcohol for one hour, then to absolute (100%) alcohol for no more than one hour.

From absolute alcohol transfer the tissue to a xylol, a clearing agent, (also called xylene) to prepare the tissues for embedding in wax. Xylol is used to remove the alcohol from the tissues to enable paraffin to enter the tissue spaces. Keep the tissue in xylol for two to three hours. If the xylol becomes cloudy return the tissue to fresh absolute alcohol; cloudiness is an indication that the tissue has not been dehydrated completely.

Embedding

When the tissues have become clear, they are ready for embedding in melted paraffin. The wax should be pre–melted and kept in a paraffin oven, or in a water bath (a watch glass should be placed over the paraffin containers, and a large glass plate over the water container). The temperature of the wax should be maintained at one or two degrees above its melting point.

The specimen should be put into a small paper container and covered with fresh paraffin (a small container can be made by folding paper into a one inch cube). After one hour the wax should be removed and fresh wax added. After another hour fresh wax should be placed in the container with the specimen. The container is then removed from the paraffin oven and allowed to cool. The cooling process can be speeded up by placing the container in cold water. After a film is formed on the top of the wax the block can be submerged. When the paraffin has hardened throughout, it can be removed from the paper container. Trim the paraffin block to a small size so it will fit the holder of the microtome and yet have wax around the specimen. Attach the block to the holder by melting one end of the block and pressing it against the holder.

Sectioning

After the block and holder have been securely attached together and mounted in the microtome, the blade and block should be set so that a section 6 to 9 microns thick can be cut. (One micron equals 1/25,000th of an inch.) As you cut, a ribbon of wax sections is formed; lift off a few sections with the help of a needle and blade and float them on slightly warmed water which covers a prepared slide. The slide should be prepared with a thin film of albumen. The water temperature must be below the melting point of the paraffin. The wax sections will expand to their maximum size (no wrinkles should form and if so, discard). Remove the water and place the slide in a drying oven set at 37°C for 24 hours. If this time is shortened, the sections may come off during the staining process.

Hydration

The wax must be removed from the slides so that the tissue can be stained. The slide is placed in xylol to dissolve the wax for five minutes. Then it is transfered to absolute alcohol for three minutes to remove the xylol. Then the slide is passed through 95%, 70%, 50%, 30% alcohols for a period of two minutes in each solution. Then, it is placed in distilled water for one minute. It is now ready to stain, since most stains are aqueous.

Staining and mounting

Normally the slide is taken from water and placed in a nuclear stain (a basic stain which colors the chromosomes, centrosomes, nucleoli, cork, cutinized epidermis and xylem tissues of plants) for two minutes. The slide is then washed in fresh water until the color fades. The dehydration process is followed up to 90% alcohol (it is the reverse of the hydration process). At this level the slide is placed into a basic (cytoplasmic) stain, for one minute. It colors the plasma, cilia and cellulose structures of the cells. The slide is then rinsed in 95% alcohol and moved to xylol, where it will remain until it is mounted in Canada balsam.

There are many acid and base stains each having its own recommended procedure for use. A few of these are listed in the section on stains.

Staining sections of Gymnosperms and Angiosperms

Materials required :

Small brushes (used in painting water colors).
Needle.
Watch glasses.
New sharp edged razor.
Slides and cover slips.
Safranin, light green, gentian voilet, orange.
Clove oil
Canada balsam.
Alcohol solutions 30%, 50%, 70%, and 100%.
Xylol.
Rubber solution (used in cycle repairing).

Procedure : Cut the part required (stem, root, leaf petiole, etc) from fresh material or-from material preserved in 70% alcohol). Cut thin and even section, with the razor. The section should be dipped in water in a watch glass. Keeping the section on the slide, exas mine it under a compound microscope. Take care that all the parts are present and clear. Transfer the section from water with a brush into a little amount of safranin in another watch glass. Keep it there for 3 to 4 minutes (if kept for a longer time, the section will take on a deep red stain). Remove the section with a brush and transfer it into 30% alcohol in another watch glass. After 3 to 5 minutes, transfer into 50% alcohol. Keep it there 3 to 5 minutes, and transfer into 70% alcohol. Here the section should be kept for 5 minutes if it is deep red or for 3 minutes if it is light in color. Then transfer it into 100% alcohol for 3 to 5 minutes. Wash it in clove oil. Add a little light green to the clove oil and keep it there for 3 to 4 minutes. Again, transfer the section into another watch glass containing clove oil. (Sections can be kept in clove oil for a longer time.) Examine the section under compound microscope. Take the section on the slide along with a drop of clove oil. Use a glass needle to place a drop of Canada balsam in the centre of the slide and place the section in the drop. Hold the coverslip in a 45° slanting position and with the needle gradually drop the coverslip very slowly while the Canada balsam is spreading. This avoids the entrance of air bubbles in the balsam. The amount of balsam should be maintained carefully, so that it should not come out of the coverslip. If the air bubbles are formed, gently warm the slide with a spirit lamp to remove them. Remove the excess balsam with xylol.

Mix xylol and the rubber solution in such a manner that a sticky liquid will be formed. After the slide has set for two or three days, seal the edges of the coverslip with the sticky xylol–rubber solution. If the slide is completely dried the seal is not necessary. If it is not dried it should be sealed to prevent air from entering.

Any sections can be stained by the above method. The combination should be either safranin and light green or gention violet and orange. Usually xylem vessels will take the safranin or violet stain and the other parts light green or orange stain.

CHEMICALS FOR MICROSCOPIC TECHNIQUES

Vital stains

1. *Methylene Blue*: Stock solution is diluted to one part stain per 10,000 parts or more of distilled water. One drop of this dilute stain will color the nucleus as well as the cytoplasmic particles.

2. *Neutral Red*: neutral red is dissolved in absolute alcohol, one part to 3000 to 30,000 parts of alcohol. It stains the nucleus lightly.

3. *Congo Red*: It is used as a stain when diluted to one part in 1000 parts of water. In the presence of weak acids it turns from red to blue.

Simple stains

1. *Iodine Stain* (*Lugol's*): It is made by dissolving 10 gm of potassium iodide in 100 ml of distilled water; then adding 5 gm of iodine. It stains the flagella, cilia and nuclei of cells.

2. *Crystal Violet*: It is made by adding 13.87 gm (or more) of the dye to 100 ml of 95% ethyl alcohol. Let it stand for two days, stirring frequently; filter and store. It is a very good stain for bacteria and protozoa.

3. *Gram's Stain*: It is another iodine stain and can be made by diluting Lugol's stain to one part in 14 parts of water. The procedure for its use is given under the topic "Gram's stain for bacteria smears."

4. *Safranin:* A basic stain for nuclear material. It is made from 3.41 gm of dye added to 100 ml of 95% ethyl alcohol It is allowed to stand for two days with frequent stirring. Filter before storing.

5. *Methyl Green*: This is a good nuclear stain for general use. It is prepared by dissolving 1 gm of dye in 1 ml of glacial acteic acid. Then diluted with distilled water to make 100 ml of 1% solution.

6. *Ethyl Eosin*: An acid dye used as a counter against nuclear stains. Prepare a 0.5% solution with ethyl alcohol.

7. *Acetocarimne*: An easy to use dye which will differentiate the nucleus nicely. Saturate a boiling 45% solution of acetic acid with carmine power then filter. Use one drop stain to one drop of protozoa culture.

8. *Basic Fuchsin:* This is a good bacteria stain prepared by adding 8.16 gm of the dye to 100 ml of 95% ethyl alcohol. Let it stand for two days stirring fequently. Filter before storing.

9. *Methylene Blue*: As a bacterial stain, 1.48 gm of dye is added to 100 ml of 95% ethyl alcohol. It is allowed to stand for two days, stirred frequently then filtered and stored. No dilutions are necessary. If used as a vital stain dilute to 1 in 10,000 parts of distilled water

10. *Delafield's Hematoxylin*: This stain may be purchased ready made or it can be made by the following procedure:

    1. Dissolve 4 gm of hematoxylin in 25 ml of absolute alcohol.
    2. Add 400 ml of a saturated aqueous solution of ammonium alum. Expose the solution to light for two days in a cotton stopped bottle. Filter.

3. Add 100 ml of methyl alcohol and 100 ml glycerin. Mix well.

4. The stain should ripen for two months at room temperature before it is ready for use.

5. Finally store in well stoppered bottles. Wash the specimens in water before putting them in this stain.

11. *Methyl Orange*: This solution is widely used as an indicator, but it also makes a good counter-stain. A 0.1% solution is made by dissolving 0.1 gm of methyl orange in 130 ml of distilled water.

Blood stains

1. *Methyl Violet*: This stain may be used to dye amphibian or human blood cells. For amphibians mix 0.05 gm of methyl violet and 0.02 ml of glacial acetic acid with 100 ml of 0.7% solution of sodium chloride. For human blood cells, use a 0.9% solution of sodium chloride.

2. *Wright's Blood Stain*: It is best to purchase this stain. The procedure for its use is in the micro-technique section under blood smears.

3. *Giemsa Stain*: The procedure for its use is under blood smears in the micro-technique section. The stain can be purchased, or can be mixed as follows: Dissolve 0.5 gm of Giemsa power in 33 ml of glycerin (this may take 1 to 2 hours) Then add 33 ml of acetone-free absolute methyl alcohol. This stock solution must be diluted one part to ten parts of distilled water for laboratory use.

Fixatives

1. *Ethyl Alcohol 70% Solution*: This is a common preservative for small forms and tissue specimens. It is made by adding 25 ml of water to 70 ml of 95% alcohol.

2. *Absolute Alcohol*: Heat crystals of cupric sulfate until only a white power remains. Add this anhydrous form to 95% ethyl alcohol. Do this until the added cupric sulfate does not turn blue in the alcohol. Then all the water is removed. Filter the alcohol quickly and store in dry stock bottles.

3. *Bouin's Fixative*: This is good fixative for general use with both animal and plant tissue. It is difficult to wash out of the tissues you wish to stain. Its main advantage is that the specimens may be stored in it for long periods of time. Mix 5 ml of glacial acetic acid and 25 ml of 40% formaldehyde with 75 ml of saturated aqueous picric acid. Leave the tissue in the fixative for 24 to 48 hours; then wash in 70% alcohol until the color is removed.

4. *Allen's Fluid*: This is an all-round general fixative. Small pieces of tissue are placed in it for 24 hours, then washed in 70% alcohol until there is no further color change. Tissue is then transferred to fresh 70% alcohol until it is used.

Allen's fluid is made by combining:

Chromic acid	1 gm
Picric acid	1 gm
Urea	1 gm
Glacial acetic acid	10 ml
Formalin (40% formaldehyde)	15 ml
Water.	75 ml

5. *Carl's Solution:* Carl's solution is an excellent preservative for insect forms. A small amount of glycerin should be added to the solution when

preserving hard bodied insects. This will stop them from becoming brittle in the preservative. The solution is made by first combining :

Ethyl alcohol (95%)	170 ml
Formalin (40% formaldehyde)	60 ml
Water	280 ml

Then just before using 20 ml glacial acetic acid is to be added to the solution.

6. *F. A. A. (Formaldehyde, Alcohol, Acetic Acid*). This is a good preservative for plants and animals. It hardens plant tissues. The tissues may be stored in this solution for years. Leaf tissue should be killed and hardened in this solution for 24 hours, woody twigs should remain in for one week. Many small animals can be fixed in this fluid. The tissues need not be washed after being preserved in F.A.A. To make F.A.A. combine the following materials:

Ethyl alcohol (95%)	50 ml
Formaldehyde (40%)	10 ml
Glacial acetic acid	2 ml
Distilled water	40 ml

7. *Preservative for Green Plants*: This solution prevents the bleaching of chlorophyll in plant tissue To F.A.A. (above) add enough copper sulfate to make a saturated solution. Specimens may be stored in this preservative indefinitely, though it is wise to transfer the specimens to fresh solution every year.

8. *Zenker's Fixative*: This is a widely used fixative in histological work, but great care must be taken because it is very poisonous (to inhale). Steel instruments will corrode in it and spoil the fixing properties. It is not very stable, only small amounts should be prepared at a time. Carefully mix together the following:

Potassium dichromate	2.5 gm
Water	100 ml
Mercuric chloride	15 gm
Sodium sulfate	1 gm
Glacial acetic acid	5 ml

The tissue should be washed in 70% alcohol for 24 hours after the tissue has soaked in the fixative for 24 hours.

9. *Flemming's Fixative*: A good fixative for careful histological study. Tissues should be kept in here for at least 24 hours, then washed in 70% alcohol for 24 hours. To make, mix together :

Osmic acid (1%)	10 ml
Chromic acid (10%)	3 ml
Water	19 ml
Glacial acetic acid	2 ml

10. *Gate's fluid*: A fixative used mainly for plant tissues; it is recommended to show chromosomes in root tips. The specimens are soaked for 24 hours in this solution then washed in running water for two hours. Combine together :

Chromic acid	0.7 gm
Glacial acetic acid	0.5 ml
Water.	100 ml

11. *Kleinenberg's Fixative* : This is a recommended fixative for chicken embryos and many small marine organisms. The tissue is to be fixed for 10 hours. then washed in 70% alcohol for one hour. It is prepared by adding picric acid to a 2% aqueous solution of sulfuric acid until the saturation point is reached.

12. *Formalin*. This stock solution is a 40% solution of formaldehyde gas in water. When formalin is used as a

fixative the stock solution is diluted to one part in ten parts of water. This is a 10% formalin solution.

Other solutions

1. *Mayer's Albumen* : This used as a glue to hold tissue sections or protozoa to the slide so that they will not come off during the dehydrating-staining process. The stock solution is made of:

Egg albumen	50 ml
Glycerin	50 ml

1 crystal thymol (or 1 gm sodium salicylate)

Shake the mixture of these chemicals vigorously so that the air bubbles become trapped in the solution. When they rise to the surface, remove the foamy mass and keep the clean liquid It will keep for 2 to 4 months without spoiling. When the solution is to be used, add 3 drops of it to 60 ml of distilled water. With a clean finger spread a very thin film on a clean slide before the solutions are added.

2. *Balsam* (*Canada Balsam*) : This is used to attach coverslips permanently to slides to protect the specimen. It comes slightly acidic and should be neutralized by sodium carbonate when working with basic stains.

3. *Methylene Cellulose* (*for slowing down protozoa* : This solution is prepared by dissolving 10 gm of methyl cellulose in 90 ml of water. Place a small ring of this on a slide and fill the circle with protozoa culture. As the methylene cellulose diffuses towards the center, the animals will be slowed down.

4. *Gelatin Solution* : A 2% to 3% gelatin solution can also be used to slow down protozoa. It is prepared by dissolving gelatin in cold water then heating gently to ensure its dissolving. One cool drop is added to a drop of culture on the slide.

5 *Potassium Oxalate or Sodium Oxalate*: Either one of these chemicals can be used for preventing mammalian blood from clotting. This is done by adding 0.1 gm of either to each 100 ml of blood.

6. *Anticoagulant for Blood* : Add 200 mg (0.2 gm) of sodium citrate to 10 ml of blood.

TECHNIQUE FOR PRESERVING PLANT PARTS IN PLASTIC CLOTH

This is a good method for preserving flowers and leaves of plants. By placing the plant parts in plastic cloth, they can easily be displayed and examined. They also can be examined with a hand lens or under the lower power objective of a microscope.

1. Collect the flowers with a few leaves and place them in castor oil for twenty four hours.

2. Press the flower and leaves in between sheets of newspaper of blotting paper in a plant press for 24 hours. If

a plant press is not available, place the flowers between many sheets of paper, Put a board on top and place some large stones on the board.

3. Wash the flowers in zylol for three hours to remove the castor oil and to make the plants soft. Arrange the flowers as you wish them to be in your plastic cloth. Press the plants dry in a plant press for another 24 hours.

4. Paint the plant parts with clear varnish. Allow the varnish to dry well.

5. Arrange the flowers on one plastic sheet; leave at least one inch of space around the flower. Cover the plastic cloth and iron them with a cool iron to seal. The plants are now protected from spoiling and will last for several years retaining their natural color.

TO PREPARE SKELETONS OF LEAVES

The leaves are immersed for two minutes in a slow-boiling solution. This solution is prepared by boiling together:

Water	500 ml
Calcium oxide	56.6 gm
Sodium carbonate	113 gm

After the solution has cooled and is filtered it is ready for use. Boil the leaves until they turn a dark brown. Then put the leaves in a shallow tray and rub them with a soft brush to remove the tissue. If the tissues do not separate from the veins, boil them again. Bleach the skeletons in a solution prepared from one liter of water and one tablespoon of calcium chloride Dry the skeletons and mount them. They can be mounted on lantern slide plates as projects.

COLLECTING AND PRESERVING ANIMALS

Collecting and examining water forms

Small water forms such as insect larva crustaceans and plankton can be collected with dip nets. A dip net is very fine cloth sewn into a bag. The open end of the bag should be reinforced with heavy wire and attached to a three foot long bamboo handle. Swish the net through a pond or well. Transfer the specimens collected in it to shallow white pans or on white paper. Examine and sort the specimens with a hand lens.

Large clean glass jars or clean buckets should be filled with water and some mud from a pond. Submerged branches and aquatic plants should be added to the jars; only a few plants should be placed in each jar. (Aquatic plants may also be transported to the laboratory in wet newspaper if they are quickly transferred to pond water in the laboratory.)

After the mud settles in the jars, the swimming specimens can be identified with a hand lens. They can be separated with the use of a small pipette. Mosquito, dragonfly, damsel fly and mayfly larvae may easily be found as well as daphnia (water flies). Microorganisms congregate at different levels in the water. For rapid inventory of bottom dwellers and surface forms which have been collected, place some clean coverslips on the bottom of the containers and float others on the surface of the water. If these coverslips are left in these positions overnight many organisms may become attached to them. Carefully remove the coverslips with forceps; place them on a drop of water on a clean slide and examine under a microscope. If you scrape the surfaces of submerged leaves and examine the scrapings under the microscope you may find protozoa such as vorticella, amoeba, flat worms, insect eggs, rotifers and some snails. Break apart swollen, rotting twigs which have been submerged; look for snails, planarians, and hydras.

The different specimens can be isolated and sub–cultured in different containers of pond water for future classroom use. Keep all these containers in moderate light and keep the containers covered to prevent evaporation.

Condensed outline of methods of collecting and preserving animals

Animal	Where found	Special collecting devices	How to kill	Fixative	Preservative
Fresh water sponges	Mid - summer in fresh water attached to branches and submerged wood	Flat bladed knife or scalpel	70% alcohol changed when it becomes discolored	70% alcohol	70% alcohol
Hydra	Canals, tanks rivers, lakes, attached to vegetation, stones, fallen leaves	Flat bladed knife or scalpel and pipette	Hot Bouin's solution flooded over specimens from base to peristome; or use menthol	Bouin's solution	70% alcohol
Fresh water planarians	Fresh spring-fed streams, tanks, canals	Fresh liver placed in water where planaria are found	Use menthol crystal method; or extend on glass side and submerge in hot Gilson's or corrosive sublimate	Gilson's or corrosive sublimate	Formalin or alcohol
Tapeworms	Intestines of dogs, cats, rabbits, sheep	Scalpel and forceps	Relax in cold water; wrap animals around support to stretch them and immerse in 10% formalin	Bouin's or formalin	Alcohol or formalin
Ascaris	Intestines of pig, horse, cat or dog	Scalpel and forceps	Dip momentarily into 98° C water	5% formalin or saturated corrosive sublimate	5% formalin or alcohol
Rotifers	Plant material taken from tanks, wells	Pipette	Anesthetize with solution of magnesium sulfate or menthol crystals	When cilia cease to move add few drops of osmic acid	Wash in water and store in 10% formalin
Pectinatella and plumatella (bryozoa)	Attached to stems, rocks leaves in streams especially in late fall	Scalpel	When fully expanded, flood with boiling Bouin's	Bouin's	70% alcohol
Earthworms	In spring on rainy nights on golf courses or bluegrass lawns	Torch light and pail	Anesthetize by slowly adding alcohol to water in which worms are placed	5% formalin	5% formalin
Leeches	Hand pick from hosts or with dip net among weeds in ponds and streams	Dip net	Anesthetize in warm chloretone or magnesium sulfate or asphyxiate in closed jar	Inject with 10% formalin and submerge in same extended position	8% formalin

From Turtox service leaflet 2, General Biological Supply House, Inc, Chicago.

Animal	Where found	Special collecting devices	How to kill	Fixative	Preservative
Crayfish	Streams, ponds lagoons, in water or burrowing in mud	Dip net, seine, or spade	Drop alive into alcohol or 8% formalin	7% alcohol or 8% formalin	70% alcohol or 8% formalin
Ticks and mites	Cattle, dogs horses, old cheese, decaying organic matter	White paper and brush for taking specimans from parasitized animals	Drop directly into 70% alcohol	70% alcohol	70% alcohol
Centipides and millipedes	Under logs or stones	Forceps	Carl's solution	Carl's solution injected into body cavity	Carl's solution
Insects	Woods, fields water, air everywhere	Net, forceps and other equipment, depending on the kind collected	For drying in killing jars; for liquid preservation in alcohol	Alcohol, Carl's solution, chloral hydrate, and special solution	70% alcohol Carl's solution or drying
Logs	In damp places, under leaves, logs, stones	No special devices	Anesthetize in boiled water which has been cooled, and immerse in formalin or alcohol	Alcohol or formalin	70% alcohol or 80% formalin
Aquatic snails	Canals, tanks, streams ponds, lakes; most abundant among vegetation	Dip net, net scraper	Anesthetize in warm water by adding magnesium sulfate causing them to expand; then drop into 10% formalin	10% formalin	8% formalin
Clams	Tanks, canals, lakes partly burried in the bottom	For large numbers, dredge or drowfoot hooks are used	Place wooden pegs between the two halves of shell and drop into 10% formalin	10% formalin	8%formalin
Lampreyr	Occasionally may be taken from fish but for large numbers must be taken in breening season in streams	Seine	Remove from water for few minutes and inject 10% formalin into body cavity	10% formalin	8% formalin
Fish	Steams, lakes tanks, canals	Nets, seines or hook and line depending or kind	Drop into full strength formalin	10% formalin	8% formalin

Animal	Where found	Special collecting devices	How to kill	Fixative	Preservative
Grassfrogs	In meadows or borders of marshy lakes	Net	Inject ether into body cavity or drop into 80% alcohol	Inject 5% formalin into body and place in 5% formalin	5% formalin
Grassfrog eggs	Shallow water of ponds in early spring when singing is started	Jars	Place in fixative	8% formalin	8% formalin
Salamanders	Damp places in woods, ponds, rivers streams, tanks canals	Hook and line or nets	Inject ether into body cavity and drop into 80% alcohol	5% formalin	5% formalin injected into body cavity
Reptiles	Woods, fields dunes, depending on kind	Shares for handling poisonous snakes; nets for capturing turtles and aquatic forms	Inject ether and drop in to 70%alcohol	10% formalin	
Birds and small mammals	Most of the world	For taxidermy purposes, a 12 guage shotgun and shells with fine shot No. 8 or 12	Bird skins are most generally used for study or reference; body is removed and skin dusted with arsenic powder; skin is then stuffed with cotton and dried		
Large mammals			Gas or drown if taken to laboratory alive	Embalm or inject 8% formalin into body and large muscles	8% formalin

Collecting insects

Collecting nets are very helpful in capturing insects. The material of the net should be a fine mesh nylon or muslin sewn into a bag with a rim of about one foot in diameter. The net should be at least two times deeper than the diameter of the rim. The net should have a stout rim and a three to six foot bamboo handle.

When hunting insects with a net, twist the net to enclose the insects in the bottom. Then transfer them into a killing jar. When flying specimens or delicate-winged lepidoptera have been captured, their wings may be damaged as they struggle within the net; this can be avoided by placing a drop of ether or chloroform on the net. Then they may be transferred to the killing jar.

Small vials will be useful in collecting arachnids, larvae, and other soft bodied forms which must be preserved immediately in alcohol. This can easily be done having a few small bottles (used medicine or injection bottles) filled with 70% alcohol. The soft bodied animals are transferred from the killing jar directly to the alcohol.

Killing jars

The standard killing jar contains potassium cyanide. The crystals are poisonous and should not be handled since the fumes are very dangerous. Great care must be taken when working with this chemical. Sprinkle (without touching) the sized bits of potassium cynide in the bottom of a large mouth jar; cover the crystals with a layer of well packed dry plaster of paris. Then, cover with a wet layer of plaster of paris. The dry layer will absorb the moisture that accumulates in the bottom from the secretions of captured insets.

A safer type of killing jar is made from packing rubber bands or spoiled bicycle tubes into the bottom of a large mouth jar, then soaking the rubber with carbon tetrachloride (or carbona). Cover this with cotton and pack tightly. To keep the cotton in place, put a large circle of cardboard on top. Since the fumes are not as lingering as cynide, lift the cardboard disk and add some more carbon tetrachloride from time to time.

When large, fragile winged specimens are placed in this killing jar, they may struggle furiously, since the fumes act slowly. To protect the wings from being damaged, wet a bit of cotton with ether or chloroform, and put this in the killing jar.

Mounting insects

It is best to mount animals soon after they are killed, because, as the time passes insects become brittle, and antenane, legs, and wings break off If the insects do become brittle before they are mounted, they may be put into a relaxing jar to soften them. Then they are placed on a spreading board if their wings are to be extended.

A relaxing jar is made from large mouth jar. Into the bottom of the jar a pad of wet cotton is packed. A few drops of carbolic acid are added to inhibit the growth of molds. Cover this with a layer of blotting paper. To use the relaxing jar, dried insects are placed on the blotting paper and the jar is covered. After twenty-four hours the insects are soft enough to handle for mounting or for spreading the wings on a spreading board. Nevertheless, they must be handled with some care, for they are not as pliable as they were when they were freshly killed. Insects such as butterflies, dragonflies and damsel flies are mounted with their wings fully extended. Grasshoppers are mounted with only one wing outspread to show the colors and pattern of the underlying wing. (This is often needed for identification of the different types of grasshoppers.) Wings of of cicadas, lace wings, and Dobson flies are also spread before they are mounted.

Spreading of insect wings

The spreader consists of three inch wide pieces of soft wood separated from each other by a 1/4 inch channel. The three inch wide pieces are layed out nearly flat with only a very small (5°) slope towards the channel. This channel should be just wide enough to accommodate the body of an insect such as a grasshopper or moth. Beneath the groove a soft cork or a few layers of blotting paper should be fixed so that the insect's body may be pinned fast. Insects such as dragon flies ,damsel flies, caddice flies, butterflies, and moths are pinned through the center of the thorax. Grasshoppers, flies, bees, wasps, squash-bugs, and the like are pinned to the right of the center of the thorax. Beetles are not pinned through the thorax at all, but through the right wing cover about a quarter of the way back.

The legs of the insects are arranged as they are in life. The wings are held in position by sheets of paper (larger than the wing) pinned over the wings to the soft wood. Pins are placed through the paper around the margin of the wings. The length of time needed for the insect to dry may vary from 1 to 7 days, depending on the body size.

Notice that the wings dry in a slightly tilted position. After the insects are finally mounted, the weight of the wings will cause the wings to droop a bit.

Displaying insects

After the animals have been spread and dried, they may be transferred to the collection box. The label should be attached by the same pin that goes through the thorax of the insect. The label (a small 1/4" × 1/2" paper) should carry the name, location, and date of collection.

Very small beetles, such as weevils, are too tiny to be pinned. These insects should be fastened to light weight, stiff paper triangles by using gum. Small fragile insects like mosquitoes should be pinned through the side of the thorax to a bit of cork; the cork is then fastened by another pin to the collection box.

To protect your insects and to control the pests which attack preserved insects, heat a few pins and insert them through chunks of paradichlorobenzene. Place a chunk in two corners of each collection box.

NUTRIENT SOLUTIONS AND MEDIA

Knop's solution for daphnia

In this method, a 6% stock solution is prepared (see below). For immediate use, add 5 liters of distilled water to a 1 liter of the stock solution. This will now be a dilute 0.1% solution. When needed, this may be further diluted with an additional 4 liters of distilled water. Even this weak solution will maintain Daphnia adequately when the culture medium has been inoculated with nonfilamentous algae and allowed to stand in light until the water becomes tinged with a green color. About once a week, add a bit of hard-boiled egg yolk paste and a bit of yeast suspension.

Combine these materials with 1 liter of distilled water and pour into several battery jars:

KNO_3	1 gm
$MgSO_4$	1 gm
K_2HPO_4	1 gm

Then add 3 gm of calcium nitrate, $Ca(NO_3)_2$. As a result a precipitate of calcium phosphate, $Ca_3(PO_4)_2$, is formed.

Chipman's method for Daphnia

Chipman recommends the following method for culturing Daphnia. A rich growth of ***Bascillus coli*** is used as the food source.

First, filter pond water through course filter paper. Then add about 90 gm of garden soil and 17 gm of cottonseed meal to 1 liter of this filtered pond water. Stir the mixture well and set it aside at room temperature for some 5 days. Fermentation takes place and gases are formed. At this time, decant off the supernatant fluid and strain through muslin. An almost pure culture of *Bacillus coli* is produced Correct the pH to 7.2 by adding sodium carbonate. Now dilute the fluid with pond water (1 part of strained fluid to 100 parts of pond water). Inoculate this culture medium with Daphnia. Keep the cultures in large battery jars. Each week prepare fresh stocks of cottonseed meal. Then add a small amount of the old culture each time a new medium is established. In this way inoculation with the original kind of bacteria is achieved.

Culture media for bacteria

1. *Meat Extract Broth*: Weigh out the following materials and then combine with 1 liter of distilled water :

Beef extract	3 gm
Peptone	10 gm
NaCl	5 gm

Heat this slowly to 65°C, stirring until the materials are completely dissolved. Then filter through paper or cotton and adjust the pH to 7.2 to 7.6. by adding a bit of sodium bicarbondate, so that a basic reaction with litmus is obtained. Pour this through a funnel into test tubes, filling them a third full, then stopper with cotton. Finally sterilize in an autoclave at 15 pounds pressure for 15 minutes. This quantity should be sufficient to prepare three dozen test tubes.

2. *Meat Extract Agar*: A liquid broth may be solidified by the addition of agar or gelatin, For example, prepare the meat extract broth previously described. Now to 1 liter of the broth add 20 to 30 gm of agar. Heat slowly until agar is dissolved. Then autoclave at 15 pounds pressure for 15 minutes Filter the solution through cotton and adjust the pH to about 7.5; then sterlize medium again. (The melting point of agar is about 99°C, and it solidifies at about 39°C.)

3. *Potato Media*: Use a cork borer to cut cylinders from large, washed and peeled potatoes. Then cut the cylinders obliquely into wedge shaped portions and leave them in running water overnight to reduce their acidity. Now put a wedge of potato into each of several test tubes. (Or use slices of potatoes in covered Petri dishes.) Add 3 ml of distilled water to each and stopper the tubes with nonabsorbent cotton. Stand the tubes in a wire basket but avoid packing them. Push down the cotton plugs so they won't pop out. Sterlize the tubes in a autoclave or pressure cooker for 20 minutes at 15 pounds pressure. Be sure to allow air to escape from the pressure cooker before closing the valve. If students use a double boiler, heat to boiling for 1 hour.

For drosophilia

1. *Cornmeal Media*: This medium uses agar. Dissolve 15 gm of agar in 750 ml of water and heat. Then add 100 gm of cornmeal and stir constantly. After this comes to a boil, add 135 ml of corn type or molasses. Boil this slowly for about 5 minutes. Then pour this medium into sterilized bottles or vials, insert towelling as before, and plug the bottles with cotton or cover with caps. This quantity will fill twenty-five culture bottles. You may want to sterilize these prepared bottles for 20 minutes at 15 pounds pressure, or add a mold inhibitor instead.

Banana Media: Dissolve 1.5 gm of agar in 47.8 ml of water by bringing it to a boil; stir well. To this add 50 gm of banana pulp made by mashing a banana with a fork or putting it through a strainer. You may want to add a trace of a mold inhibitor. (A minute quantity of Methyl Parasepts in 0.15% solution can be added; in excess any inhibitor will reduce the growth of yeast and slow down the development of the flies).

Heat the medium again so that it comes close to boiling. Then quickly pour the medium into half-pint milk bottles or glass vials to a depth of ¼ inch. It is safer to sterilize the bottles before introducing the medium. Then insert a strip of paper towelling into the medium while it is soft; this will provide additional space for egg laying and pupation. Cover the bottles with cotton wrapped in muslin. Tilt the bottles against a ledge to increase the surface, and allow them to cool. You may want to pour medium from the cooking pot through a funnel into the bottles so that the medium does not spill along the sides of the bottles. Store the bottles in a cool place until the flies are to be introduced. Just before using the bottles to accept the flies, add 2 to 3 drops of a rich yeast suspension to the surface of the solid medium. Or add a pinch of dried yeast; this will dissolve in the fluid on the surface.

4. *Wheat Media*: This preparation eliminates the agar. Measure out 77.5 ml of water, 11.5 ml of molasses and 10 3 gm or cream of wheat. Add the molasses to two thirds of the water; bring to a boil. Mix the cream of wheat with the remaining third of cold water and add this to the boiling contents and boil again. Pour the medium into sterlized bottles, add strips of toweling, stopper the bottles, and tilt them as before.

5. *Fertilizer for acid-loving plants*: Place the plants to be grown in acid media in sawdust containing one pound of the mixture of the following salts per 5 cubic feet of saw dust.

$(NH_4)_2 SO_4$	26 parts
Superphosphate	31 parts
Potash	190 parts

Half to half garden loam and this mixture serves well for plants also.

BIOLOGICAL SOLUTIONS

Solutions which test for nutrients

1. *Lugol's Solution – Test for Starch* : Dissolve 10 gm of potassium iodide in 100 ml of distilled water. Then add 5 gm of iodine. Place one drop of this solution onthe object to be tested. A blue black color formation indicate starch is present.

2. *Benedict's Solution - Qualitative Test for Simple Sugars* : In the presence of simple sugars a yellow or reddish precipitate of cuprous oxide forms when the solution is heated with the known media. It can be purchased or it can be prepared by dissolving 173 gm of sodium (or potassium) citrate and 200 gm of sodium carbonate (crystalline) in 700 ml of distilled water. Then filter. Dissolve 17.3 gm of crystalline copper sulfate in 100 ml of water. Slowly mix these two solutions. Add distilled water to make one liter and allow to cool.

3. *Fehling's Solutions – Test for Simple Sugars* : Equal amounts of the two Fehling's solutions are added to a bit of the substance to be tested, and then heated. A yellow or redish precipitate forms if sugar is present. Fehling's solutions can be purchased, or they may be prepared, separately :

Solution I

$CuSO_4$	35 gm
Distilled water	500 ml

Solution II

KOH	125 gm
Potassium sodium tartrate	173 gm
Distilled water.	500 ml

4. *Million's Reagent–Test for Proteins* : The stock solution is made by dissolving 100 gm of mercury in 200 ml of nitric acid (sp. g. 1.42). To use, dilute this by three volumes of distilled water. Place a small piece of protein substance in a few drops of the reagent. The protein will precipitate into a red solid on heating (heat slowly).

Absorbers and indicators

1. *Potassium Pyrogallote Solution*: This solution is used to remove oxygen from a closed quantity of air. Mix 1 part by weight of pyrogallic acid, 5 parts potassium hydroxlde, and 30 parts water. Place a small vial of this solution in the closed container from which you must remove the oxygen. (Keep this solution stored in a tightly sealed container.)

2. *Potassium Hydroxide – To Absorb Carbon Dioxide* : The pellets or a solution made by dissolving a few pellets in water can be used effectively to remove CO_3 form the air. Place the potassium hydroxide in such a manner that the animal or plants will not get into the material.

3. *Cobalt Chloride Paper–Indicator of Moisture* : This paper is used to demonstrate that leaves give off water. The filter paper with cobalt chloride on it is attached to a leaf with a piece of cellophane protecting the paper from contact with the air. Cobalt chloride paper should be used when it is blue. On contract with water it will become pink.

To prepare these sheets, immerse filter paper in a 5% solution of aqueous cobalt chloride. Blot the paper dry between additional sheets of filter paper. Dry them in an oven set at 40°C. Cut the paper into desired sizes. For immediate use, dry the paper quickly in a test tube over a flame until the paper turns from pink to blue. The paper can be stored in large mouth, tightly stopped bottles containing a layer of anhydrous calcium chloride covered with cotton.

4. *Anhydrous Calcium Chloride-Moisture Absorber*: Calcium chloride can be heated to drive out all the water in it. The crystals when cool will readily absorb moisture from the air. This material can be retreated if it has absorbed water and has become "chalky" and soft.

Saline solutions

1. *Ringer's Solution for Frog Tissue* This solution being isotonic for frog tissue, is used as a mounting fluid for living frog tissue. A frog's heart will beat for several hours after being cut out of the frog if kept in this solution. To make, dissolve the following salts in one liter of distilled water.

$CaCl_2$	0.12 gm
KCl	0.14 gm
NaCl	6.50 gm
$NaHCO_3$	0.20 gm

2. *Ringer's Solution for Mammalian Tissue*: This solution is used as a mounting fluid for examination of living tissues. It is isotonic for mammalian tissues. And the following salts to one liter of distilled water.

$CaCl_2$	0.24 gm
KCl	0.42 gm
NaCl	9.00 gm
$NaHCO_3$	0.20 gm

3. *Physiological Saline Solution*: For cold blooded animals. It is used as a mounting fluid in the preparation of temporary wet mounts. In this solution cold blooded animal cells will neither shrink nor swell. It is a 0.7% solution of sodium chloride in distilled water. Add 0.7 gm (100 mg) of NaCl to 100 ml of distilled water.

4. *Physiological Saline Solution for Warm Blooded Animals*: This is used as a mounting flluid for warm blooded animals. Make a 0.9% solution of sodium chloride in distilled water by dissolving 0.9 gm NaCl in 100 ml of distilled water. The following amounts of these salts added to one liter of distilled water will help maintain pH at 7.38 in a solution.

NaH_2PO_4	28.81 gm
$NaHPO_4$	125.00 gm

5. *Hayems Solution*: This solution is used as the diluting solution in preparing blood for red blood cell counts. It is often used as a stain for blood smears when 0.05 gm of eosin is added to the solution indicated here. Before making the smear mix one part of blood to 100 parts of this stain. Then make the blood smear on a clear slide. Weigh out these salts and add them to 100 ml of distilled water.

$HgCl_2$	0.25 gm
Na_2SO_4	2.50 gm
NaCl	0.50 gm

Some solutions for the stockroom

1. *Acid Starch Solution*: Immediately before the acid starch solution is needed, add five drops of yellowish nitric acid (containing nitrous acid) to 10 ml of the starch solution.

In an alternative method, add 1 ml of dilute $NaNO_2$ solution and 1 ml of dilute H_2SO_4 to 10 ml of starch solution just before it is to be used.

2. *Starch Paste* : to test enzyme reaction add a small amount of cold water to 1 gm of mida starch and stir in to a paste. Then add this to 100 ml of boiling water; stir constantly keeping at a boil, and then let it cool. This is a satisfactory strength for general use in demonstrations of salivary digestion (1% Solution).

3. *Sucrose Solution* : Dissolve 34.2 gm of sucrose in a half liter of water. Add additional water to make one liter. Add tolvene as a preservative. This makes as 0.1 *M* solution.

4. *Stop Cock Lubricant* : Glycerin prevents sticking of ground glass parts and is also useful in sealing ground joints to prevent leaking of substances which are insoluble in it (such as ether).

5. *Lime Water* : A test for the presence of carbon dioxide

To distilled water add an excess of calcium hydroxide or calcium oxide. Stop the bottle, shake well, and let it stand for 24 hours, then pour off the supernatant fluid (filter if necessary) and keep well stopped.

The lime water should remain clear. When carbon dioxide is added, a milky precipitate of calcium carbonate is formed

$$CO_2 + H_2O = H_2CO_3$$
$$Ca(OH)_2 + H_2CO_3 = CaCO_3 + 2H_2O$$

6. *Rennin Solution* : Prepare a 0.1% solution grinding up 1 gm of rennin and adding to 50 ml of water to form a thin paste. Dilute with water to 1 liter.

MODELS

Imitation of a living cell

Materials : Water 500 ml, copper sulphate 43 gm, ammonium ferrocynide or potasium ferrocyanide – one or two crystals.

Procedure : Put 500 ml of water in a glass jar (or big bottle-mouth cut off. Dissolve 43 gm of copper sulphate in it. Generally a milky precipitate is formed. This can be removed by adding a few drops of H_2SO_4. Now add a crystal of ammonium ferrocyanide or potassium ferrocynide to the solution. The growth and some other characters of a living cell will be noticed.

How it works : A thin film of copper ferrocyanide is formed on the crystal. By the process known as a diffusion, there will be an increase of pressure which makes the skin stretch and later split. Then the ferrocyanide comes into contact with the copper sulphate solution again and a new skin forms, closing up the hole.

This goes on until the crystal has dissolved. The growth may be to a length of four inches. When the crystal dissolves, it lossess the ability to close the little holes. Then it tears and slowly shrivels.

This chemical cell reacts to stimuli

from outside just like a living cell. It grows upwards, even though the base is at an angle. In the sunlight, the growing point looks green. If the cell is punctured the holes close up.

Problem : How can we stop the growth of this chemical cell?

Modelling wax for biology specimens

White wax	20 parts
Turpentine	4 parts
Sesame oil	1 part
Vermillion-(Ingilikom)	2 parts

Melt the wax. Add turpentine slowly by stirring; add sesame oil. Finally add vermillion.

Modelling clay for biological models

Clay or Fuller's earth (kaolin)
Vaseline/glycerine

Take good clay. Mix it with water in a bucket until it becomes a uniform creamy substance. Filter it through a thick cloth. Spread newspapers in a bamboo tray and pour the filtrate into it. Allow it to dry completely. Power the dried clay and sieve through a thick cloth. You get very fine clay powder free from most of the sand. Take this powder and mix glycerine little by little until you get a plastic mass. Knead it well. You can mix a little vaseline if it is too hard. This clay never dries. You can use it for the preparation of models any number of times.

(If you use Fuller's earth you can directly mix it with glycerine).

CHEMICAL TECHNIQUES

General Rules of Solubility

1. Soluble in H_20
2. Insoluble in H_20

Preparing Solutions

1. Strengths of solutions
2. Percentage by volume
3. Molar solutions
4. Normal solutions
5. Conversion of molar solutions
6. Molarity of purchased acids or bases
7. Standard reagents
8. Useful solutions

pH and pH Indicators

1. pH of a solution
2. pH values of a variety of acids and bases (table)
3. Indicators
4. Range of indicators
5. Solutions of pH indicators
6. Buffers

Spectacular Demonstrations

1. Oxygen as a fire make
2. Fire by adding water
3. Chemical fires
4. Harmless explosives
5. Heat of reaction
6. Hypo to remove stains
7. Blotting paper to remove ink
8. Preparation of ink from tea

Paper Chromatography.

GENERAL RULES OF SOLUBILITY

Soluble in water

Compounds of sodium, potassium and ammonium. Sulfates (except silver and mercury chloride; lead chloride is slightly soluble).

Insoluble in water

Phosphate, carbonates, oxides, sulfides, sulfates and silicates (except those of sodium, potassium and ammonium)

Hydroxides (except those of sodium, ammonium, and potassium; calcium barium and strontium hydroxides are slightly soluble).

PREPARING SOLUTIONS

Strength of solutions

In common practice, when a dilute solution is prepared, such as a 1% solution of sodium chloride, 1 gm of the salt is added to 100 ml of water. Actually this results in a solution the concentration of which is slightly below 1%. When the concentration is 10%, the error involved in the common practice becomes significant. Therefore, to make a 10% solution of sodium chloride that is accurate enough for most purposes, add 10 gm of salt to a graduated cylinder; then add water up to the 100 ml mark.

Percentage by volume-making dilutions

To prepare a solution, the concentration of which is measured by volume, begin by measuring out (in millilitres) a volume of the higher percentage solution that is equal in number of millilitres to the percentage needed for the new solution. For example, when you have 70% alcohol on hand and want to prepare 50% alcohol, measure out 50 ml of the 70% alcohol. Then add a enough distilled water to bring the volume to a number of millilitres equal to the percentage of the original solution (in this example, to 70 ml).

Molar solutions

A molar solution is a solution containing one gram/molecule of the dissolved substance per litre of solution (not solvent). To prepare a molar solution dissolve a number of grams equal to the molecular weight of the substance in water (or other solvent) and make up to one litre. For example, sodium chloride has a molecular weight of 58.45. A molar solution of sodium chloride (written 1 *M* NaCl) contains 58.45 gm of sodium chloride in one liter of solution. We can also make dilutions of molar solutions, such as 0.1 *M* and so forth A 0.4 *M* solution of sodium chloride contains $58.45 \times 0.4 = 23.38$ gm of NaCl per liter of solution.

Normal solutions

One gram/equivalent of a substance in 1 liter of solution will result in a normal solution of that compound. A gram equivalent is the amount of the substance equivalent to 1 gram atom of hydrogen.

Thus normal solution of an acid contains one gram-atom of reacting hydrogen per liter of solution; any other normal solution can then replace or react quantitatively with an equal volume of solution.

To prepare normal solutions study the formula of the acid, base or salt to be dissolved. When there is one hydrogen atom or one hydroxyl group or one of any ion which will combine with one hydrogen atom or one hydroxl group, a normal solution is the same as a molar solution. When two hydrogen atoms are present, as in H_2SO_4, a normal solution contains half as much H_2SO_4 as a molar solution because there are two gram equivalents in every gram mole.

In general, a normal solution is prepared by dissolving in one liter of solution a quantity of acid, base or salt determined in the following way:

$$\frac{\text{Number of grams needed for 1 } M \text{ solution}}{\text{Number of equivalents to 1H in each molecule.}}$$

or

$$\frac{\text{Molecular weight of substance in grams.}}{\text{Valence}}$$

Conversion of molar solutions

You have a stock solution of 1 *M* hydrochloric acid. You want to prepare 50 ml of 0.1 *M* of HCl solution.

Method: Take 1/10 of the desired volume of the more concentrated solution and then add enough distilled water to bring this volume up to the final volume sought. In the above example take 5 ml of 1 *M* HCl and make it up to 50 ml. Then you should get a 0.1 *M* HCl solution. To dilute a solution in physical units you can do it by the following method.

You have a sample of NaCl solution containing 40 grams per liter and you want to dilute it to 10 grams per litre. Take a quantity of the stock solution and dilute it four times as the volume of the sample. In the above example if 20 ml of the stock solution is diluted, the final volume must be $4 \times 20 = 80$ ml of final solution whose concentration is 10 grams/liter.

The principle is:

1 liter × 40 gm/liter=4 liter × 10 gm/liter; $V_1 \times C_1 = V_2 \times C_2$

Molarity of purchased acids or bases

Example: A mole of HCl has a mass of 36.5 gm So 3.65 gm of HCl if diluted to 1 liter volume yields 0.1 *N* HCl. However, this is 3.65 gm of anhydrous hydrogen chloride in one liter of solution,not 3.65 gm of the concentrated hydrochloric acid on hand in the laboratory. How may we determine volume of concentrated hydrochloric acid which will contain 3.65 gm of hydrogen chloride? We can do it from the assay information printed on the label of the bottle of concentrated hydrochloric acid.

Suppose the concentrated HCl is 38.15% HCl by weight. Its specific gravity is 1.2. One ml of the solution has a mass of 1.2 gm of which 38.15% is HCl. One ml then contains:

$$0.3815 \times 1.2 = .45780 \text{ gm of HCl}$$

The volume of solution needed to provide 3.65 gm of HCl is 3.65÷.4578 gm/ml= 7.97 ml of conc. HCl.

Example 2: To calculate the weight of sulphuric acid in 1 ml of the purchased sample the following calculations are performed.

$$\begin{aligned} &\text{Weight of } H_2SO_4 = \\ &\text{density} \times \text{weight percent} \\ &= \frac{1.84 \text{ gm} \times .96}{\text{ml}} \\ &= \frac{1.83}{\text{ml}} \end{aligned}$$

1 liter of solution would contain :

$$= \frac{1.803}{\text{ml}} \times \frac{1000}{1} = \frac{1803}{1} \text{ gm}$$

Since one mole $H_2SO_4 = 98$ gms to find the molarity of the solution divide the weight dissolved in a liter of solution by the weight of 1 mole

$$M = \frac{1803}{1} \times \frac{\text{Mole}}{98\text{gm}} = 18.4\ M$$

Since the weight of a gram - equivalent of H_2SO_4 is 49 gm the normality of the purchased solution is calculated in the same manner as the molarity except that the weight of H_2SO_4 per liter of solution is divided by the equivalent weight of the acid.

$$N = \frac{1803}{1} \times \frac{\text{Gram/Equi}}{49 \text{ g}} = 36.8\ N$$

Standard reagents acids and bases

1. *Ammonium Hydroxide* : Use concentrated C.P. NH_4OH for 15 *M*. If you dilute 400 ml of this to one liter you will get 6 *M*; 167 ml of this 6 *M* if diluted to 1 liter it yields 1 *M*.

2 *Hydrochloric acid*: Concentrated C.P. HCl is 12 *M*. To prepare 6 *M* HCl take 100 ml of 12 *M* HCl and add 100 ml of water. To prepare a 0.1 *M* dilution add 167 ml of 6 *M* HCl to 1 liter of water.

3. *Nitric acid* : Concentrated C. P. HNO_3 is 16 *M*. To prepare 6 *M* HNO_3 mix 375 ml of 16 *M* acid with 625 ml of water.

4. *Sulphuric acid* : Concentrated C.P. H_2SO_4 is 18.4 *M*. To prepare 3*M* or 6 *N* add 167 ml of 18 *M* solution to approximately 500 ml of H_2O and then dilute it to one liter. Note : Add the acid to the water slowly by stirring.

To prepare 1 *N* dilute 167 ml of 3 *M* H_2SO_4 to one liter.

5. *Acetic acid* : Glacial acetic acid of 99.5% is 17 *M*. If you dilute 353 ml of 17 *M* acetic acid to 1 liter, you will get 6 *M* solution. If 59 ml of 17 *M* acid is diluted to 1 liter, 1 *M* solution results.

6. *Sodium Hydroxide* : Dissolve 200 gm of C.P. NaOH in water and dilute it to 1 liter resulting in a 5 *M* solution.

Hand stock solutions

1. *Ammonium Chloride* : One formula weight of it is to be dissolved in water and the solution is made up to 1 liter (1 *M* concentration).

2. *Calcium Hydroxide* : 0.02 *M* (saturated). Keep an excess of solid $Ca(OH)_2$ in a large bottle fitted with a siphon. Fill with water, agitate the mixture, let it settle, and siphon off the clear liquid as needed. Add water as necessary to replenish.

3. *Chlorine Water* : Use $KMnO_4$ and [illegible] 2 *M* HCl and produce the gas. Pass the gas through water.

4. *Cupric Sulphate*: Dissolve 125 gms of $CuSO_4–5H_2O$ in one liter of water (0·5 *M* concentration).

5. *Ferric Chloride*: Dissolve 27 gm of $FeCl_3–6\ H_2O$ in one liter of water.

6. *Cobalt Nitrate*: 49.5 gm of $Co(No_3)_2 - 6H_2O$ are dissolved in a liter of water resulting in a 2.2 *M* solution.

7. *Iodine*: Take 12.7 gm of iodine and 53 gm of potassium iodide in 200 ml of water· Dilute it to one liter yielding a 0.1 *M* solution.

8· *Lead Acetate*: Dissolve 37·9 gm of hydrated salt in water and make up to one liter. Makes 0.1 *M* solution.

9. *Litmus*: 10 gm of litmus powder is to be dissolved in 100 ml of water and then diluted to 1000 ml.

10. *Lead Nitrate*: 33.1 gm of lead nitrate is dissolved in water and diluted to 1 liter. $Pb(No_3)_2 = .1\ M$

11. *Mercuric Chloride*: Dissolve 27.3 gm of solution mercuric chloride per liter of water resulting in $HgCl_2$ in a 0.1 solution.

12. *Oxalic Acid*: Take 63 gm of the hydrated acid. Dissolve in a little water and dilute it to 100 ml resulting in 0.5 *M* solution.

13. *Potassium Fericyanide*: In a little water dissolve 32.9 gm of the salt and make up to 1 liter resulting in a 0.1 *M* solution $K_3Fe(CN)6–3H_2O$

14. *Potassium Bromide*: Dissolve 11.9 gm of the salt per liter making a 0.1 *M* solution.

15. *Potassium Ferocynaide*: Dissolve 42.2 gm of $K_4Fe_4(CN)_4–3H_2O$ per liter for a 0.1 *M* solution.

16. *Potassium Hydroxide*: 56.1 gm of KOH are dissolved per liter making a 0.1 *M* solution.,

17. *Potassium Iodide*: 16.1 gm per liter making a 0.1 *M* solution.

18. *Potassium Nitrate*: 10.1 gm per liter makes 0.1 *M* solution.

19. *Silver Nitrate*: Dissolve 17.0 grams of $Ag\ NO_3$ per liter for a 0.1 *M* solution. *Note*: The solution should be stored in an amber coloured bottle.

20. *Sodium Carbonate*: 106 gm of sodium carbonate is dissolved in 200 ml of water and diluted to a liter for a 1 *M* solution.

21. *Sodium Chloride*: Dissolve 58.3 gm per liter for a 1 *M* solution.

22. *Sodium Chloride Solution*: (*saturated*) Add about 37 gm of NaCl to 100 ml of water; if the resulting solution is not saturated add a bit more of the salt.

23. *Sodium Chloride Solution* (0.1 *M*): Dissolve 5.85 gm of NaCl in water to make one liter of solution.

24. *Sodium Hydroxide Solution* (1 *M*): Dissolve 40 gm of NaOH in 200 ml of water. Dilute with water to one liter of solution.

25. *Sodium Bicarbonate*: Take 84 gm of $NaHCO_3$ per liter for a 1 *M* solution.

26. *Sodium Thiosulphate*: Dissolve 248 gm of $Na_2S_2O_3–5H_2O$ per liter for a 1 *M* solution.

27. *Stannic Chloride*: Take 35.1 gm of $SnCl_4–5H_20$. Dissolve in 167 ml of 12 *M* HCl. Warm a little and dilute it to liter for a 1 *M* concentration.

28. *Stannous Chloride*: Dissolve 113 gm $SnCl_2–2H_2O$ in 125 ml of 12 *M* HCl by heating the solution until the Solid dissolves completely for a 5 *M* solution.

Dilute to 1000 ml. Put a little piece of metalic tin in the solution to prevent oxidation.

pH AND INDICATORS

The pH of a solution

A pH value is designated as the logarithm of the number of liters of a solution needed to get one gram of hydrogen ions. Pure water is slightly ionised; there is one gram of hydrogen ions (otherwise stated as "one gram ion" of hydrogen) in every 1,00,00,000 liters. That is, the hydrogen ion concentration is 1/1,00,00,000 of a gram of ions in every liter. Another way of stating this same thing is to say that the concentration is 10^{-7} H^+ ions per liter. Thus we say the pH of pure water is seven (7) and likewise, this is defined as the neutral point on the pH scale. Since the concentration of H^+ gram ions in a 0.1 *N* solution of H_2SO_4 is $10^{-1.2}$ its pH is said to be 1.2. Likewise there is one gram of H ions in 10,000,000,000,000 (also written as 10^{13}) liters of, 1 *N* NaOH. Thus the concentration of one gram of H^+ in one liter is 1/10,000,000,000,000 or 10^{-13} gram ions of hydrogen and its pH value is 13.

The pH value is therefore said to be a measure of the acidity or the alkalinity of a solution with a neutral solution having a value of 7. Acid solutions have a value of less than 7 and allkaline solutions have a value greater than 7. If an acid is added to pure water, the hydrogen ion concentration increases, hence pH decreases.

pH VALUE OF 0.1 *N* SOLUTIONS OF A VARIETY OF ACIDS AND BASES

Acids	pH value	Bases	pH value
Decreasing strength		**Increasing strength**	
Hydrochloric acid	1.0	Sodium bicarbonate	8.4
Sulfuric acid	1.2	Borax	9.2
Phosphoric acid	1.5	Ammonia	11.1
Sulfurous acid	1.5	Sodium carbonate	11.3
Acetic acid	2.9	Trisodium phosphate	12.0
Alum	3.2	Sodium metal silicate	12.2
Carbonic acid	3.8	Lime (saturated)	12.3
Boric acid	5.2	Sodium hydroxide	13.0

Indicators

Indicators are dyes that are used to test the pH of a solution. As the hydrogen-ion content of the solution changes, variations within the acid or alkaline range and from one end of the scale to the other can be measured by the use of certain indicators. Notice that some of the indicators commonly used in demonstrations are those that show a shift in pH around neutral (7).

Solutions of pH indicators

Alizarin Red: 1 percent aqueous solution.

Brom Thymol Blue: Add 0 04 gm of brom thymol blue powder to 614 ml of 0.01 *N* NaOH, add 20 ml of absolute alcohol. Make up final volume to 100 ml with distilled water. In use, add 9 ml of liquid of solution to be tested to 1 ml of stock solution.

Congo Red: 0.5% solution in 50% alcohol.

Methyl Orange: 0.02% aqueous solution.

Methyl Red: 0.02% solution in 50 % alcohol.

Phenolphthalein: Prepare a 0.5% solution in alcohol by dissolving 0.5 gm of phenophthalein in 100 ml of 95% alcohol. For very sensitive tests 0.1% solution may be used.

Additional indicators may be prepared as follows:

Grind 0.05 gm of the indicator (see list below) with the designated volume of 0.01 *N* sodium hydroxide solution in a mortar; add distilled water to make 125 ml of the indicator solution (increase proportions if larger quantities are required).

Brom Cresol Green: 7.2 ml of 0.01 *N* NaOH

Brom Cresol Purple: 9.3 ml of 0.01 *N* NaOH

Brom Phenol Blue: 7.5 ml of 0.01 *N* NaOH

Brom Thymol Blue: 8.0 ml of 0.01 *N* NaOH

Chlorophenol Red: 11.8 ml of 0.01 *N* NaOH

Cresol Red: 13.1 ml of 0.01 *N* NaOH
Meta Cresol Purple: 13.1 ml of 0.01 *N* NaOH

Phenol Red: 14.1 ml of 0.01 *N* NaOH
Thymol Blue: 10.8 ml of 0.01 *N* NaOH

Buffer

A substance which when added to a solution, causes a resistance to any change in pH. A solution containing a relatively high concentration of a buffer salt which tends to maintain a constant pH.

The pH of a weak acidic or alkaline solution tends to remain practically constant, regardless of the addition of other ions, if the proper salts are present. In acetic acid solution containing a fairly high concentration of sodium acetate, the hydrogen ion concentration will not vary appreciably Similarly the hydroxide ion concentration in an ammonia water solution will remain almost constant if the solution contains a high concentration of ammonium chloride. Salts used in this way are called buffer salts.

Buffer action has many applications in chemistry and physiology. The human blood is buffered so as to maintain a pH of about 7·3. If there is a pronounced change, it will lead to serious disturbance of normal functions, or even death.

A biological buffer can be made by adding the following salts to one liter of distilled water.

NaH_2PO	28.81 gm
Na_2PO_4	125.00 gm

RANGE OF CERTAIN INDICATORS

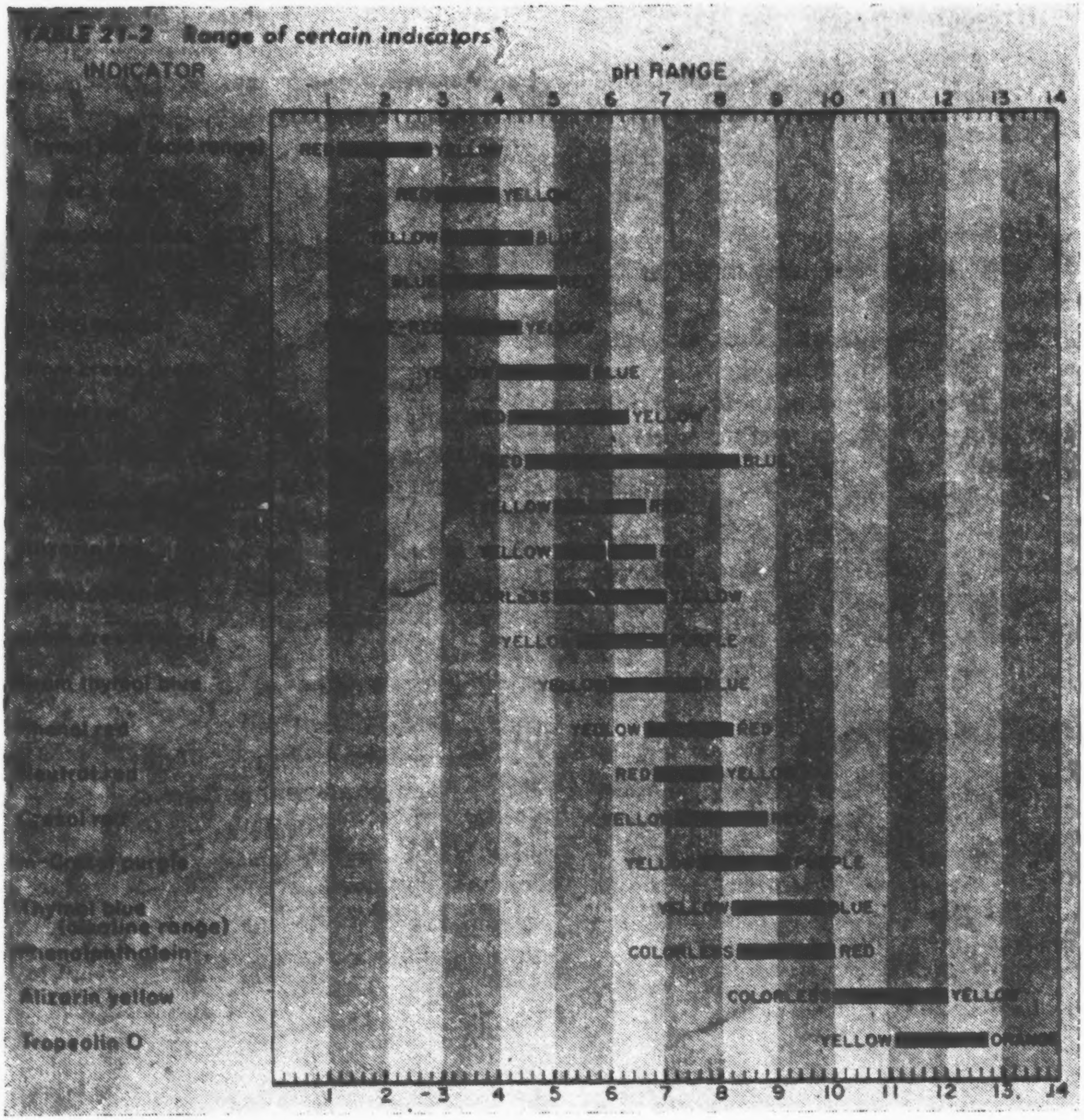

TABLE 21-2 Range of certain indicators*

SPECTACULAR DEMONSTRATIONS

Materials:

1. Hydrogen peroxide
2. Manganese dioxide
3. Matches
4. 6" test tube
5. Broom straw

Demonstration: Put enough hydrogen peroxide in the test tube to fill it to a depth of about an inch. Then add a pinch of manganese dioxide and carbon. The liquid in the tube will bubble and fizz. The manganese dioxide causes the hydrogen peroxide to break up rapidly into water and oxygen. The bubbles in the tube are bubbles of oxygen. Light a broom straw and blow out the flame so that only a red hot ember remains at the end. Thrust this into the test tube. It will glow brightly and burst into flame.

Fire by adding water

Mix equal amounts of iodine crystals and aluminium. Place this mixture on a stone or hard surface. Add a few drops of water and a violent reaction will take place giving off clouds of purple smoke.

Chemical fires

Materials :

1. Potassium permanganate
2. Glycerine

On a plain white paper powdered potassium permanganate is placed. Four or five drops of glycerine are dropped on it. Potassium permanganate oxidizes glycerine. The heat of reaction is so great that the paper catches or fire. If glycerine is warmed a little or the potassium permanganate is warmed, the reaction will be immediate. The experiment is not effective in a dark room.

Materials :

1. A crystal of iodine
2. A small piece of yellow phosphorous

On a plain white paper the piece of phosphorus is put and it is touched with a small crystal of iodine by means of a spatula made from strapping. Both the elements combine together to form phosphorus triodide and phosphorus pentaiodide. The heat of reaction is enough to light the paper.

Materials :

1. Cane sugar crystals
2. Powdered potassium chlorate
3. Concentrated sulphuric acid

Place the powdered materials on some paper and drop the sulphuric acid. The sugar is charred to carbon by H_2SO_4 and this carbon is oxidized by $KC10_3$

Harmless explosives

Materials:

1. Iodine
2. Potassium iodide
3. Liquor ammonia

Stir 3 gm of potassium iodide and 5 gm of iodine in 50 cc of water. Add 20 cc of ammonia and stir until no more precipitate is formed. Filter. Extract the wet solid and put it on blotting paper. Allow it to dry in the shade for 6 hours. Cut the blotting paper into pieces. These papers explode violently with the slightest pressure or disturbance. Do not make piles of crystals larger than 1 gm.

Another method is to put the crystals of iodine in ammonia overnight. They are filtered the next day and the precipitate or the solid particles are dried slowly. Sprinkle the crystals on the floor. Nitrogen is formed in the above procedures and it explodes with the slightest disturbance due to its instability.

Heat of reaction

We require equal quantities of potassium permanganate and citric acid. Mix and put them on a piece of paper and add a drop or two of water. Water is the agent which brings chemical reaction. The acid is oxidized and intense heat is developed.

This reaction is used to cauterize the wound caused by a scorpion bite.

Hypo removes stains

Add 10 drops of tincture of iodine to 1/4 glass full of clear water and stir the mixture. It will have a light yellow colour. Add 1/2 teaspoonful of hypo and stir again. The liquid will instantly lose its yellow colour and become clear. Now put a drop or two of iodine on a cloth. When it becomes dry put the cloth in a solution of sodium thiosulphate (hypo). The stain will disappear.

Blotting paper to remove ink

1.	Alcohol	4 parts
2.	Oxalic acid	1 part

Immerse porous white paper in the solution. Dry the paper on threads. Before use, moisten it. It removes ink spots.

Preparation of ink from tea

Materials :

1. Tea leaves
2. Ferrous sulphate

Pour one cupfull of water into a small pan and heat it until it boils. Then remove it from the fire and add one half teaspoon full of tea leaves. Allow the tea leaves to soak in the hot water for five minutes. The tannic acid from the leaves goes into solution in the hot water. Strain the leaves out of the tea. Add another half teaspoonful of tea leaves and repeat this process two more times. Then add a 1 gm to 1.5 gm of ferrous sulphate. Stir well until it dissolves. Keep overnight and filter.

PAPER CHROMATOGRAPHY

Chromatography is a convenment method for separating a mixture of compounds dissolved in a solvent. It can be done quantiatively, but in the classroom qualitative separation is normally done. One procedure is to use an 8" disk of filter paper that has two parallel cuts, 1 cm apart, to the center of the disk.

The strip is then folded down into a vertical position forming a wick and placed into a beaker of solution containing the mixture. Only one inch of the strip should be in the solution. The rest of the disk covers the top of the beaker.

If a large quantity of the solution containing the mixture is not available, the spot procedure can be used. Use a concentrated solution containing the mixtures of ink and make a line or a spot on the filter paper wick so that it will be one inch above the solvent level. If a disk of paper is not available a long strip of filter paper can be used as the wick. Let it hang freely in a vertical line so that one inch of the paper is in the solution.

Separation on the disk paper will appear as a series of different colored rings around the center. On the strip of paper different colored bands will be found above the original mark or solution. The separation is due to the different diffusing rates of the compounds. The faster moving molecules will go farther from the solvent.

In chemistry a separation of various dyes and inks can easily be done. Some dyes separate into different pigments; mixtures of dyes can be separated into different colors. The solvents normally used for these experiments are water or a slightly acidic medium.

In biology a popular experiment is the separation of plant pigments. Carotene, xanthophylls and chlorophylls found in green leaves separate into distinct bands. There are two methods for extracting the pigments from the leaves. One is to crush 10 gm of leaves in 20 ml of acetone. The pigments are dissolved by the acetone (the solvent in the beaker, therefore should be acetone). The second method uses methyl or ethyl alcohol. First the leaves are boiled in water for five minutes to soften them by breaking down the cell walls. Then the leaves are soaked in warm alcohol for five minutes. In this case alcohol is used as the solvent in the beaker.

PHYSICS TECHNIQUES

Silvering of Mirrors

1. First method.
2. Second method.
3. Cane sugar method.

Solutions and Aids

1. Sodium light.
2. Dry lubricant to reduce friction.
3. Dry batteries.
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Tables

1. Definitions and formulas.
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10. Atomic weights.
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12. Density of various solids.
13. Surface tension.
14. Approximate E.M.F's of cells.
15. Pressure of saturated water vapor
16. Relative humidities from wet and dry bulb thermometers.
17. Thermal conductivity of gases.
18. Acid dilution by volume.
19. General rules regarding behavior of metals and certain compounds.
20. Greek alphabet.

SILVERING OF MIRRORS

Purpose: To make concave, convex and plane mirrors.

Materials required:

Silver nitrate.
Distilled water.
Ammonium hydroxide.
Sodium potassium tartrate or rochelle salts.

Procedure: Prepare the solutions as follows:

Solution 1: Take 237 ml of distilled water. Boil it. Add 776 mg of silver nitrate and 776 mg of Rochelle salts. Boil for 6 to 7 minutes, cool and filter. The filtrate is put in an amber colored bottle and labelled as stock solution No. 1.

Solution 2: Take 237 ml of distilled water. Take a small quantity into a tumbler and add 583 mg of $AgNO_3$. Stir well until dissolved. Add several drops of ammonia until the solution becomes clear. Add an additional 1.04 gm of $AgNO_3$ stirring well until dissolved. Add the balance of the distilled water and filter through a glass funnel. Keep the solution in an amber colored bottle and label it as stock solution No. 2.

Process of Silvering – Convex mirror: Clean a watch glass with ammonia and wipe it with a clean wet cloth. Take 6 ml of solution No. 1 and solution No. 2 in a small glass tumbler. Mix well. Pour the mixture in the watch glass and put it on a water bath. When precipitation is complete, remove it from the water bath and allow it to cool. After some time, pour off all unused liquid and allow the watch glass to dry. Then slowly wash it with running water. Give a coating of red lead mixed in varnish over the silver coating.

Concave mirror: Take a glass tumbler, whose bottom diameter is a little larger than that of the watch glass. Put the watch glass in it so that the convex part shows up. Cover the watch glass with a mixture of equal volumes of stock solutions. Warm the tumbler in a water bath. When precipation is complete pour off and unused solution and allow the watch glass to dry. Remove it from the tumbler and coat the silvering with red lead mixed with varnish.

Second method

Solution:

Silver nitrate	25 gm
Distilled water	29·6 ml

Take 7.5 ml of solution. Add ammonia until the precipitate redissolves. Add 104 ml of distilled water. Add 80 drops of formaldehyde (40%). Use this mixture to silver the glass. Heating is not required.

The silvering vessel is made out of wood and then it is suitably lined with candle wax to keep the object to be silvered just touching the solution.

Silvering glass using cane sugar

Reducing Solution : This is to be prepared a week before it is used.

Distilled water	700 ml
Pure cane sugar	80 gm
When dissolved add alcohol.	175 ml
Concentrated nitric acid	3 ml

Silvering Solution :

Silver nitrate	6.7 gm
Caustic potash	3.35 gm

Dissolve the silver nitrate in 67 ml of distilled water and dissolve caustic potash in 33 ml of water. Keep them separate.

Take silver nitrate solution. Pour a few drops of dilute ammonia solution, until the precipitate is formed, nearly redissolve the precipitate formed by the addition of potash. The precipitate should not dissolve completely. A brown color should be seen.

A quantity of reducing solution equal to about one fourth part of the solution just prepared is measured out. The mirror having been properly cleaned and rinsed with distilled water is placed in a tray or a dish. The reducing solution and the silver solution are now mixed thoroughly and the mixture is poured over the glass.

The solution first turns black, then to brown and finally to gray. This takes 15 minutes. Then the operation is at an end. Remove the mirror and rinse with water. The water is removed with a clean blotting paper.

Sodium light

A paper is to be soaked in a saturated solution of sodium salt and dried. It is wrapped around the bunsen burner, secured by a twist of wire and pushed up into the edge of the flame. As the ash of the paper breaks away the paper is occasionally raised. A sodium flame of considerable intensity is obtained.

Dry lubricant to reduce friction

Melt paraffin and add as much powdered graphite as is readily moistened by the liquid paraffin. Cool and cut while soft into convenent sticks.

The lubricant when rubbed on the surface involved, greatly reduces friction. It is especially useful for non-metallic substances.

If we make a wheeled cart for experiments on laws of motion and the like, this lubricant is very useful to reduce friction between the axle and the wheel.

Dry batteries

Make a solution of the following :

NH_4CL	8 parts

HgCl	1 part
HCl	1 part

Then add NaCl to this solution to make a paste. This paste can be used between plates of carbon and zinc or it can be filled in zinc containers with a carbon rod in the middle. ZnO–1, NH_4Cl–1, plaster of paris-3, $ZnCl_2$–1, water–2. MnO_2 is first stuffed around the carbon rod in a zinc container and then the remaining space is filled with the above mixture.

To determine electric polarity

Moisten filter paper with 1% solution of phenolpthalein in alcohol. Allow it to dry. They dip it in a 10% solution of KCl. For use, wet the paper and apply to the terminals. The negative side turns pink. Electrolysis takes place and at the negative pole and KOH forms.

DEFINITIONS AND FORMULAS

Absorption: 1. Penetration of a substance into the body of another. 2. Transformation into other forms suffered by radiant energy passing through a material substance.

Absorption spectrum: The spectrum obtained by the examination of light from a source, itself giving a continuous spectrum, after this light has passed through an absorbing medium in the gaseous state. The absorption spectrum will consist of dark lines or bands, being the reverse of the emission spectrum of the absorbing substance.

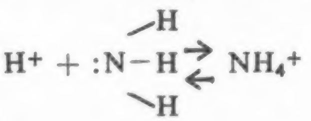
When the absorbing medium is in the solid or liquid state the spectrum of the transmitted light shows broad dark regions which are not resolvable into lines and have no sharp or distinct edges.

Acid: For many purposes it is sufficient to say that an acid is a hydrogen-containing substance which dissociates on solution in water to produce one or more hydrogen ions. More generally, however, acids are defined according to other concepts. The Bronsted concept states that an acid is any compound which can furnish a proton. Thus NH_4^+ is an acid since it can give up a proton:

$$NH_4^+ = NH_3 + H^+$$

and NH_3 is a base since it accepts a proton.

A still more general concept is that of G. N. Lewis which defines an acid as anything which can attach itself to something with an unshared pair of electrons. Thus in the reaction



$$H^+ + :\overset{\nearrow H}{\underset{\searrow H}{N}}-H \rightleftarrows NH_4^+$$

the NH_3 is a base because it possesses an unshared pair of electrons. This later concept explains many phenomena, such as the effect of certain substances other then hydrogen ions in the changing of the color of indicators. It also explains acids and bases in non-aqueous systems as liquid NH_3 and SO_2.

Adsorption : The condensation of gases, liquids, or dissolved substances on the surfaces of solids is called adsorption.

Alternating current, (A-C) : Current in which the charge-flow periodically reverses, as opposed to direct current, and whose average value is zero. Alternating current usually implies a sinusoidal variation of current and voltage. This behavior is represented mathematically in various ways :

$$I = I_o \cos (2 \pi ft + \phi)$$
$$I = I_o 7 \phi$$
$$I = I_1 e^{j\omega t}$$

where f is the frequency ; $\omega = 2\pi f$, the pulsatance, or radian frequency; ϕ the phase angle ; I_o the amplitude ; and I_1 the complex amplitude. In the complex rotation, it is understood that the actual current is the real part of L. For circuits involving also a capacitance C in farads and L in henrys, the impedance becomes,

$$\sqrt{R^2 + \left(2 \pi fL - \frac{1}{2 \pi fC}\right)^2}$$

Ampere's rule : A positive charge moving horizontally is deflected by a force to the right if it is moving in a region where the magnetic field is vertically upward. This may be generalized to currents in wires by recalling that a current in a certain direction is equivalent to the motion of positive charges in that direction. The force felt by a negative charge is opposite to that felt by a positive charge.

Amplitude: The maximum value of the displacement in a oscillatory motion.

Angle : The ratio between the arc and the radius of the arc. Units of angle, - the radian, the angle subtended by an arc equal to the radius ; the degree, 1/360 part of the total angle about a point.

Angstrom : A unit of length, used especially in expressing the length of light waves, equal to one ten-thousandth of a micron, or one hundred millionth of a centimeter (1×10^{-8} cm).

Anhydride (of acid or base). An oxide which when combined with water gives an acid or base.

Anode : The electrode at which oxidation occurs in a cell. It is also the electrode toward which anions travel due to the electrical potential. In spontaneous cells the anode is considered negative. In non-spontaneous or electrolytic cells the anode is considered positive.

Archimedes principle : A body wholly or partly immersed in a fluid is buoyed up by a force equal to the weight of the fluid displaced. A body of volume V cm^3 immersed in a fluid of density ρ grams per cm^3 is buoyed up by a force in dynes,

$$F = \rho gV$$

where g is the accleration due to gravity. A floating body displaces its own weight of liquid.

Atom : The smallest particle of an element which can enter into a chemical combination. All chemical compounds are formed of atoms, the difference between compounds being attributable to the nature, number, and arrangement of their constituent atoms.

Atomic mass (atomic weight) : The mass of a neutral atom of a nuclide.

It is usually expressed in terms of the physical scale of atomic masses, that is, in atomic mass units (amu).

Atomic number: The number (Z) of protons within the atomic nucleus. The electrical charge of these protons determines the number and arrangement of the outer electrons of the atom, and thereby the chemical and physical properties of the element.

Atomic theory: All elementary forms of matter are composed of very small unit quantities called atoms. The atoms of a given element all have the same size and weight. The atoms of different elements have different sizes and weights. Atoms of the same or different elements unite with each other to form very small unit quantities of compound substances called molecules.

Atomic weight: Atomic weight is the the relative weight of the atom on the basis of oxygen as 16. For a pure isotope, the atomic weight rounded off to the nearest integer gives the total number of nucleons (neutrons and protons) making up the atomic nucleus. If these weights are expressed in grams they are called gram atomic weights– See *Atomic Mass*.

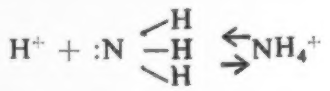
Avogadro's law: Equal volumes of different gases at the same pressure and temperature contain the same number of molecules.

Avogadro's number: The number of molecules in one mole or gram-molecular weight of a substance. A number of values of the Avogadro number, which is usually denoted by N, have been found by various methods, generally lying within a range of 1% about the value $(6.02486 \pm 0.00016) \times 10^{23}$ per gram-mole (physical). $(6{,}2322 \pm 0.0016) \times 10^{23}$ per gram-mole (chemical).

Bases: For many purposes it is sufficient to say that a base is a substance which dissociates on solution in water to produce one or more hydroxyl ions. More generally, however, bases are defined according to other concepts. The Bronsted concept states that a base is any compound which can accept a proton. Thus NH_3 is a base since it can accept a proton to form ammonium ions

$$NH_3 + H^+ \rightleftarrows \pm NH_4^+$$

A still more general concept is that of G. N. Lewis which defines a base as anything which has an unshared pair of electrons. Thus in the reaction



$$H^+ + :N \begin{matrix} -H \\ -H \\ -H \end{matrix} \rightleftarrows NH_4^+$$

the NH_3 is a base because it possesses an unshared pair of electrons. This latter concept explains many phenomena, such as the effect of certain substances other than hydrogen ions in the changing of the color of indicators. It also explains acids and bases in non-aqueous systems as liquids NH_3 and SO_2.

Beat (s): Two vibrations of slightly different frequencies f_1 and f_2 when added together, produce in a detector sensitive to both these frequencies, a regularly varying response which rises and falls at the "beat" frequency $f_b = |f_1 - f_2|$. It is important to note that a resonator which is sharply tuned to f_b alone will not resound at all in the presence of these two beating frequencies.

Beat frequencies: The beat of two different freqencies of signals on a non-linear circuit when they combine or beat together. It has a frequency equal to difference of the two applied frequencies.

Beronoulli's theorem: At any point in a tube through which a liquid is flowing the sum of the pressure energy, potential energy, and kinetic energy is constant. If p is pressure; h, height above a reference plane; d, density of the liquid, and v, velocity of flow,

$$p + hdg + \tfrac{1}{2}dv^2 = \text{a constant.}$$

Black body: If, for all values of the wavelength of the incident radiant energy, all of the energy is absorbed the body is called a black body.

Bohr's atomic theory: The theory that atoms can exist for a duration solely in certain states, characterized by definite electronic orbits, i e., by denfinite energy levels of their extra-nuclear electrons, and in these stationary states they do not emit radiation; the jump of an electron from an orbit to another of a smaller radius is accompaned by monochromatic radiation.

Boyle's law for gases: At a constant temperature the volume of a given quantity of any gas varies inversely as the pressure to which the gas is subjected. For a perfect gas, changing from pressure p and volume v to pressure p' and volume v' without change of temperature,

$$pv = p'v'$$

British thermal unit: The quantity of heat required to raise the temperature of one pound of water one degree Fahrenheit at, or near its point of maximum density (39. 1°F). The Btu is equivalent to 0.252 kilogram-calorie.

Brownian movement: A continuous agitation of particles in a colloidal solution caused by unbalanced impacts with molecules of the surrounding medium. The motion may be observed with a microscope when a strong beam of light is caused to traverse the solution across the line of sight.

Calorie: The amount of heat necessary to raise 1 gram of water at 15°C, 1°C. There are various calories depending upon the interval chosen. Sometimes the unit is written as the gram calorie or kilogram calorie, the meaning of which is evident. The calorie may be defined in terms of its mechanical equivalent. The National Bureau of. Standards defines the calorie as 4.18400. joules. At the International Steam Table Conference held in London in 1929 the international calorie was defined at 1/860 of the international watt hour, which makes it equal to 4.1860 international joules

Candle (or International Candle): The candle is the unit of luminous intensity. It is a specified fraction of the average horizontal candlepower of a group of 45 carbon-filament lamps preserved at the Bureau of Standards.

Candle (New Unit): 1/60 of the intensity of one square centimeter of a blackbody radiator at the temperature of solidification of platinum (2,046°K).

Capacitance is measured by the charge which must be communicated to a body to raise its potential one unit. Electrostatic unit capacitance is that which requires one electrostatic unit of charge to raise the potential one electrostatic unit. The farad$=9\times10^{11}$ electrostatic units. A capacitance of one farad requires one coulomb of electricity to raise its potential one volt.

Charles' law or Gay-Lussac's law: The volumes assumed by a given mass of a gas at different temperatures, the pressure remaining constant, are, within moderate ranges of temperature, directly proportional to the corresponding absolute temperature.

Christiansen effect: When finely powdered substances, such as glass or quartz, are immersed in a liquid of the same index of refraction, complete transparency can only be obtained for monochromatic light. If white light is employed, the transmitted color corresponds to the particular wavelength for which the two substances, solid and liquid, have exactly the same index of refraction. Due to differences in dispersion the indices of refraction will match for only a narrow band of the spectrum.

Chromatic aberration: Due to the difference in the index of refraction for different wavelengths, light of various wavelengths from the same source cannot be focused at a point by a simple lens. This is called chromatic aberration.

Colloid: A phase dispersed to such a degree that the surface forces become an important factor in determining its properties.

In general, particles of colloidal dimensions are approximately 10 angstroms to 1 micron in size. Colloidal particles are often best distinguished from ordinary molecules due to the fact that colloidal particles cannot diffuse through membranes which do allow ordinary molecules and ions to pass freely.

Combining volumes: Under comparable conditions of pressure and temperature the volume ratios of gases involved in chemical reactions are simple whole numbers.

Combining weight of an element or radical is its atomic weight divided by its valence.

Combining weights, law of: If the weights of elements which combine with each other be called their "combining weights," then elements always combine either in the ratio of their combining weights or of simple multiples of these weights.

Component substances, law of: Every material consists of one substance, or is a mixture of two or more substances, each of which exhibits a specific set of properties, independent of the other substances.

Compounds are substances containing more than one constituent element and having properties, on the whole, different from those which their constituents had as elementary substances. The composition of a given pure compound is perfectly definite, and is always the same no matter how that compound may have been formed.

Condensers in parallel and series: If c_1, c_2, c_3 etc. represent the capacitances of a series of condensers and C their combined capacitance,—

when in parallel, $C = c_1 + c_2 + c_3 \ldots$

when in series, $\frac{1}{C} = \frac{1}{c_1} + \frac{1}{c_2} + \frac{1}{c_3} \ldots$

Conductance, the reciprocal of resistance, is measured by the ratio of the current flowing through a conductor to the difference of potential between its ends. The practical unit of conductance, the mho, the conductance of a body through which one ampere of current flows when the potential difference is one volt. The conductance of a body in mho is the reciprocal of the value of its resistance in ohms.

Conductivity, electrical, is measured by the quantity of electricity transferred across unit area, per unit potential gradient per unit time. Reciprocal of resistivity. **Volume conductivity** or specific conductance, $k = 1/\rho$ where ρ is the volume resistivity. **Mass conductivity**$=k\ d$ where d is density. **Equivalent conductivity** $\Lambda = k/c$ where c is the number or equivalents per unit volume of solution. **Molecular conductivity** $\mu = k/m$ where μ is the number of moles per unit volume of solution.

Conductivity, thermal: Time rate of transfer of heat by conduction, through unit thickness, across unit area for unit difference of temperature. It is measured as calories per second per square centimeter for a thickness of one centimeter and a difference of temperature of 1°C.

If the two opposite faces of a rectangular solid are maintained at temperatures t_1 and t_2 the heat conducted across the solid of section a and thickness d in a time T will be,

$$Q = \frac{K(t_2 - t_1)aT}{d}$$

K is a constant depending on the nature of the substance, designated as the specific heat conductivity. K is usually given for Q in calories, t_1 and t_2 in °C, a in cm^2, T in sec, and d in cm.

Conductors ; A class of bodies which are incapable of supporting electric strain. A charge given to a conductor spread to all parts of the body.

Conservation of energy, law of: Energy can neither be created nor destroyed and therefore the total amount of energy in the universe remains constant.

Conservation of momentum, law of: For any collision, the vector sum of the momenta of the colliding bodies after collision equals the vector sum of their momenta before collision. If two bodies of masses m_1 and m_2 have, before impact velocities v_1 and v_2 and after impact velocities u_1 and u_2

$$m_1u_1 + m_2u_2 = m_1v_1 + m_2v_2$$

Coulomb: A unit quantity of electricity. It is the quantity of electricity which must pass through a circuit to deposit 1110.0080 grams of silver from a solution of silver nitrate. An ampere is one coulomb per second. A coulomb is also the quantity of electricity on the positive plate of a condenser of one-farad capacity when the electromotive force is one volt.

Current (electric): The rate of transfer of electricity. The transfer at the rate of one electrostatic unit of electricity in one second is the electrostatic unit of current. The electromagnetic unit of current is a current of such strength that one centimeter of the wire in which it flows is pushed sideways with a force of one dyne when the wire is at right angles to a magnetic field of unit intensity. The practical unit of current is the **ampere,** a transfer of one coulomb per second, which is one tenth the electromagnetic unit. The **international ampere** is the unvarying electric current which, when passed through a solution of silver nitrate in accordance with certain specifications, deposits silver at the rate of 0.00111800 gram per second. The international ampere is equivalent to 0.999835 absolute ampere. The **ampere-turn** is the magnetic potential produced between the two faces of a coil of one turn carrying one ampare.

Dalton's law of partial pressures: The pressure exerted by a mixture of gases is equal to the sum of the separate pressures which each gas would exert if it alone occupied the whole volume. This fact is expressed in the following formula :

$$pV = V(p_1 + p_2 + p_3, \text{ etc.})$$

Dew point : The temperature at which condensation of water vapor in the air takes place.

Diffraction : That phenomena produced by the spreading of waves around and past obstacles which are comparable in size to their wavelength.

Diffusion : If the concentration (mass of solid per unit volume of solution) at one surface of a layer of liquid is d_1 and at the other surface d_2, the thickness of the layer h and the area under consideration A, then the mass of the substance which diffuses through the cross-section A in time t is,

$$m = \Delta A \frac{(d_2 - d_1)\, t}{h}.$$

where Δ is the coefficient of diffusion.

Diffusivity : or coefficient of diffusion is also given by Δ in the equation

$$\frac{dQ}{dt} = -\Delta\left(\frac{dc}{dx}\right) dy\, dz$$

where dQ is the amount passing through an area $dy\, dz$ in the direction of x in a time dt where dc/dx is the rate of increase of volume concentration in the direction of x.

Diminution of pressure at the side of a moving stream : If a fluid of density d moves with a velocity v, the diminution of pressure due to the motion is (neglecting viscosity),

$$p = \tfrac{1}{2} dv^2$$

Doppler effect, (Light) : The apparent change in the wavelength of light produced by the motion in the line of sight of either the observer or the source of light.

Doppler effects: Effects on the apparent frequency of a wave train produced (1) by motion of the source toward or away from the stationary observer, and (2) by motion of the observer toward or from the stationary source; the motion in each case being with reference to the (supposedly stationary) medium.

For sound waves, the observed frequency f_o, in cycles/sec., is given by

$$f_o = \frac{v+w-v_o}{v+w-v_s} f_s$$

where v is the velocity of sound in the medium, v_o is the velocity of the observer, v_s is the velocity of the source, w is the wind in the direction of sound propagation, and f_s is the frequency of source.

For optical waves

$$f_o = f_s \sqrt{\frac{c + v_r}{c - v_r}}$$

where v_r is the velocity of the source relative to the observer and c is the speed of light.

Dulong and Petit, law of : The specific heats of the several elements are inversely proportional to their atomic weights. The atomic heats of solid elements are constant and approximately equal to 6.3. Certain elements of low atomic weight and high melting point have, however, much lower atomic heats at ordinary temperatures.

Elastic moduli. *Young's modulus by stretching.* If an elongation s is produced by the weight of the mass m, in a wire length l, and radius r, the modulus,

$$M = \frac{mgl}{\pi r^2 s}$$

Young's modulus by bending, bar supported at both ends. If a flexure s is produced by the weight of mass m, added midway between the supports separated by a distance l, for a rectangular bar with vertical dimensions of cross-section a and horizontal dimension b, the modulus is,

$$M = \frac{mgl^3}{4sa^3b}$$

For a cylindrical bar of radius r,

$$M = \frac{mgl^3}{12\pi r^4 s}$$

For a bar supported at one end. In the case of a rectangular bar as described above,

$$M = \frac{4mgl^3}{sa^3b}$$

For a round bar supported at one end,

$$M = \frac{4mgl^3}{3\pi r^4 s}$$

Modulus of rigidity: If a couple C $(=mgx)$ produces a twist of θ radians in a bar of length l and radius r, the modulus is

$$M = \frac{2Cl}{\pi r^4 \theta}$$

The substitution in the above formulas for the elastic coefficients of m in grams, g in cm per sec^2, l, a, b, and r in cm, s in cm, and C in dyne–cm will give moduli in dynes per cm^2.

Coefficient of restitution: Two bodies moving in the same straight line, with velocities v_1 and v_2 respectively, collide and after impact move with velocities v_3 and v_4. The coefficient of restitution is

$$C = \frac{v_4 - v_3}{v_2 - v_1}$$

Electrochemical equivalent of an ion is the mass liberated by the passage of unit quantity of electricity.

Electrolysis: If a current i flows for a time t and deposits a metal whose electrochemical equivalent is e, the mass deposited is

$$m = eit$$

The value of e is usually given for mass in grams, i in amperes and t in seconds.

Electromotive force is defined as that which causes a flow of current. The electromotive force of a cell is measured by the maximum difference of potential between its plates. The electromagnetic unit of potential difference is that against which one erg of work is done in the transfer of electromagnetic unit quantity. The **volt** is that potential difference against which one joule of work is done in the transfer of one coulomb. One volt is equivalent to 10^8 electromagnetic units of potential. The **international** volt is the electrical potential which when steadily applied to a conductor whose resistance is one international ohm will cause a current of one international ampere to flow. The international volt = 1.00033 absolute volts. The electromotive force of a

Weston standard cell is 1.0183 int. volts at 20°C.

Electron: The electron is a small particle having a unit negative electrical charge, a small mass, and a small diameter. Its charge is (4.8094 ± .00008) × 10^{-10} absolute electrostatic units, its mass 1/1837 that of the hydrogen nucleus, and its diameter about 10^{-12} cm. Every atom consists of one nucleus and one or more electrons. Cathode rays and beta rays are electrons.

Elements are substances which cannot be decomposed by the ordinary types of chemical change, or made by chemical union.

Energy: The capability of doing work. **Potential energy** is energy due to position of one body with respect to another or to the relative parts of the same body. **Kinetic energy** is energy due to motion. Cgs units, — the **erg**, the energy expended when a force one dyne acts through a distance of one centimeter; the **joule** is 1 × 10^7 ergs.

The potential energy of a mass m, raised through a distance h, where g is the acceleration due to gravity is

$$E = mgh.$$

The kinetic energy of mass m, moving with a velocity v, is

$$E = \frac{1}{2}mv^2$$

Energy will be given in ergs if m is in grams, g in cm per sec^2, h in cm and v in cm per sec.

Energy of rotation: If a mass whose moment of inertia about an axis is I, rotates with angular velocity ω about this axis, the kinetic energy of rotation will be,

$$E = \frac{1}{2}\omega^2$$

Energy will be given if I is in g-cm^2 and ω in radians per sec.

Equilibrium, chemical: A state of affairs in which a chemical reaction and its reverse reaction are taking place at equal velocities, so that the concentrations of reacting substances remain constant.

Equilibrium constant: The product of the concentrations (or activities) of the substances produced at equilibrium in a chemical reaction divided by the product of concentrations of the reacting substances, each concentration raised to that power which is the coefficient of the substance in the chemical equation.

Equivalent weight or combining weight: Of an element or ion is its atomic or formula weight divided by its valence. Elements entering into combination always do so in quantities proportional to their equivalent weights.

In oxidation-reduction reactions the equivalent weight of the reacting substances is dependent upon the change in oxidation number of the particular substance.

Expansion of gases - *Charle's law or Gay-Lusac's law*: The volume of a gas at constant pressure increases proportionately to the absolute temperatures. If V_1 and V_2 are volumes of the same mass of gas at absolute temperatures, T_1 and T_2.

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

For an original volume at 0°C the volume at t°C (at constant pressure) is

$$V_t = V_0 (1 + 0.00367t).$$

General law for gases.

$$p_t v_t = p_o v_o \left(1 + \frac{t}{273}\right)$$

where p_o, v_o, p_t, n_t, represent and value at O° and $t^\circ C$ or

$$\frac{p_1 v_1}{T_1} = \frac{p_2 v_2}{T_2}$$

where p_1, v_1 and T_1 represent pressure, volume and absolute temperature in one case and p_2, v_2 and T_2 the same quantities for the same mass of gas in another.

The law may also be expressed :

$$pv = RmT$$

where m is the mass of gas at absolute temperature T. R is the **gas constant** which depends on the units used. **Boltzemann's molecular gas constant** is obtained by expressing m in terms of the number of molecules.

For volume in cm³, pressure in dynes per cm² and temperature in centigrade degrees on the absolute scale R= 8.3136×10^7.

Reduction of a gas volume to 0°C, 760 mm pressure: If V is the original volume of a gas at temperature t and pressure H, the volume at O°C and 760 mm pressure will be,

$$V_o = \frac{V}{(1 + \alpha t)} \frac{H}{760}$$

If d is the original density the density at O°C and 760 mm pressure will be

$$d_o = d\,(1 + \alpha t)\frac{760}{H}$$
$$\alpha = 0.00367 \text{ approximately.}$$

Falling bodies: For bodies falling from rest conditions are as for uniformly accelerated motion except that $v_o = 0$ and g is the acceleration due to gravity. The formulae become, —air resistance neglected,

$$v_t = gt, \quad s = \tfrac{1}{2}gt^2, \quad v_s = \sqrt{2gs}$$

For bodies projected vertically upward, —if v is the velocity of projection, the time to reach greatest height, neglecting the resistance of the air,

$$t = \frac{v}{g}$$

Greatest height,

$$h = \frac{v^2}{2g}$$

Faradays' laws : In the process of electrolytic changes equal quantities of electricity charge or discharge equivalent quantities of ions at each electrode.

One gram equivalent weight of matter is chemically altered at each electrode for 96,501 int. coulombs, or one faraday, of electricity passed through the electrolyte.

Fission: A nuclear reaction from which the atoms produced are each approximately half the mass of the parent nucleus. In other words, the atom is split into two approximately equal masses. There is also the emission of extremely great quantities of energy since the sum of the masses of the two new atoms is less than the mass of the parent heavy atom. The energy released is expressed by Einstein's equation.

Fleming's rule: A simple rule for relating the directions of the flux, motion, and e. m. f. in an electric machine. The forefinger, second finger and thumb, placed at right-angles to each other, represent respectively the directions of flux, e. m. f., and motion or torque. If the right hand is used the condition are those obtained in a generator. If the left hand is used the conditions are those obtained in a motor.

Force: That which changes the state of rest or motion in matter, measured by the rate of change of momentum. Absolute unit,—the **dyne**, the force which will produce an acceleration of one centimeter per second per second in a gram mass. The gram weight or weight of a gram mass is the cgs gravitational unit. The poundal is that force which will give an acceleration of one foot per second per second to a pound mass.

The force F required to produce an acceleration a in a mass m is given by

$$F = ma.$$

If m is substituted in grams and a in cm per sec^2, F will be given in dynes.

Force between two magnetic poles: If two poles of strength m and m' are separated by a distance r in a medium whose permeability is μ (unity for a vacuum), the force between them is,

$$F = \frac{mm'}{\mu r^2}$$

Force will be given in dynes if r is in cm and m and m' are in cgs units of pole strength.

The strength of a magnetic field at a point distance r from an isolated pole of strength m is

$$H = \frac{m}{\mu r^2}$$

The field will be given in gauss if m and r are in cgs units.

Friction, coefficient of: The coefficient of friction between two surfaces is the ratio of the force required to move one over the other to the total force pressing the two together.

If F is the force required to move one surface over another and W, the force pressing the surfaces together, the coefficient of friction,

$$k = \frac{F}{W}$$

Fusion (atomic): A nuclear reaction involving the combination of smaller atomic nuclei or particles into larger ones with the release of energy from mass transformation. This is also called a thermo-nuclear reaction by reason of the extremely high temperature required to initiate it.

Gay-Lussac's law of combining volumes: If gases interact and form a gaseous product, the volumes of the reacting gases and the volumes of the gaseous products are to each other in simple proportions, which can be expressed by small whole numbers.

Graham's law: The relative rates of diffusion of gases under the same conditions are inversely proportional to the square roots of the densities of those gases.

Gram atom or gram atomic weight: The mass in grams numerically equal to the atomic weight.

Gram equivalent: Of a substance is the weight of a substance displacing or otherwise reacting with 1.008 grams of hydrogen or combining with one-half of a gram atomic weight (8.00 grams) of oxygen.

Gram mole, gram formula weight, gram equivalent: Mass in grams numerically equal to the molecular weight, formula weight or chemical equivalent, respectively.

Gram molecular weight or gram molecule: A mass in grams of a substance numerically equal to its molecular weight. Gram mole.

Gravitation: The universal attraction existing between all material bodies. The force of attraction between two masses m and m', separated by a distance r, k being the constant of gravitation,

$$F = k\,\frac{mm'}{r^2}$$

(If m and m' are given in grams, in centimeters, F will be in dynes if and $k = 6.670 \times 10^{-8}$).

Heat capacity: That quantity of heat required to increase the temperature of a system or substance one degree of temperature. It is usually expressed in calories per degree centigrade.

Molar heat capacity is the quantity of heat necessary to raise the temperature of one molecular weight of the substance one degree.

Heat equivelent, or latent heat, of fusion: The quantity of heat necessary to change one gram of solid to a liquid with no temperature change.

Heat of combustion of a substance is the amount of heat evolved by the combustion of 1 gram molecular weight of the substance.

Heat quantity: The cgs unit of heat is **the calorie**, the quantity of heat necessary to change the temperature of one gram of water from 3.5° to 4.5°C (called a small calorie). If the temperature change involved is from 14.5 to 15.5°C, the unit is the normal calorie. The mean calorie is 1/100 the quantity of heat necessary to raise one gram of water from 0°C to 100°C. The large calorie is equal to 1000 small calories. The British thermal unit is the heat required to raise the temperature of one pound of water at its maximum density, 1°F. It is equal to about 252 calories.

Heisenberg's theory of atomic structure: The currently accepted view of the structure of an atom, formulated by Heisenberg in 1934, according to which the atomic nuclei are built of nucleons, which may be protons or neutrons, while the extranuclear shells consist of electrons only. The nucleons are held together by nuclear forces of attraction, with exchange forces operating between them. The number of protons is equal to the atomic number (Z) of the element, the number of neutrons is equal to the difference between the mass number and the atomic number (A–Z). The number of excess neutrons, i.e., the excess of neutrons over protons, is of paramount importance for the radioactive properties or stability of the element.

Henry's law: The mass of a slightly soluble gas that dissolves in a definite mass of a liquid at a given temperature is very nearly directly proportional to the partial pressure of that gas. This holds for gases which do not unite chemically with the solvent.

Hooke's law: Within the elastic limit of any body the ratio of the stress to the strain produced is constant.

Humidity, absolute: Mass of water vapor present in unit volume of the atmosphere, usually measured as grams per cubic meter. It may also be expressed in terms of the actual pressure of the water vapor present.

Hydrogen ion concentration : The concentration of hydrogen ions in solution when the concentration is expressed as gram-ionic weights per liter. A convenienient form of expressing hydrogen ion concentration is in terms of the negative logarithm of this concentration. The negative logarithm of the hydrogen ion concentration is called pH.

Water at 25°C has a concentration of H ion of 10^{-7} and of OH ion of 10^{-7} moles per liter. Thus the pH of water is 7 at 24°C. A greater accuracy is obtained if one substitutes the thermodynamic activity of the ion for its concentration.

Index of refraction for any substance is the ratio of the velocity of light in a vacuum to its velocity in the substance. at is also the ratio of the sine of the angle of incidence to the sine of the angle of refraction. In general, the index of refraction for any substance varies with the wavelength of the refracted light.

Inductance : The change in magnetic field due to the variation of a current in a conducting circuit causes an induced counter–electromotive force in the circuit itself. This phenomenon is known as **self-induction**. If an electromotive force is induced in a neighboring circuit the term mutual induction is used. Inductance may thus be distinguished as self or mutual and is measured by the electromotive force produced in a conductor by unit rate of variation of the current. Units of inductance are the centimeter (absolute electromagnetic) and the henry, which is equal to 10^9 centimeters of inductance. The **henry** is that inductance in which an induced electromotive force of one volt is produced when the inducing current is changed at the rate of one ampere per second.

Inertia : The resistance offered by a body to a change of its state of rest or motion, a fundamental property of matter.

Ion: An ion is an atom or group of atoms that is not electrically neutral but instead carries a positive or negative electric charge. Positive ions are formed when neutral atoms or molecules lose valence electrons; negative ions are those which have gained electrons.

Kinetic theory, expression for pressure :

$$P = \frac{1}{3} Nmv^2$$

Where N is the number of molecules in unit volume, m the mass of each molecule and v^2 the mean square of the velocity of the molecules.

Kinetic theory of gases: Gases are considered to be made up of minute, perfectly elastic particles which are ceaselessly moving about with high velocities, colliding with each other and with the walls of the containing vessel. The pressure exerted by a gas is due to the combined effect of the impacts of the moving molecules upon the walls of the containing vessel, the magnitude of the pressure being dependent upon the kinetic energy of the molecules and their number.

Lenses : For a single thin lens whose surfaces have radii of curvature r_1 and r_2 whose principal focus is F, the index of refraction n, and conjugate focal distances f_1 and f_2,

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} = (n-1)\,\frac{1}{r_1}\;\;\frac{1}{r_2}$$

For a thick lens, of thickness t,

$$F = \frac{n r_1 r_2}{(n-1)\,[n(r_1 + r_2) - t(n-1)]}$$

Loschmidt's number : The number of molecules per unit volume of an ideal gas at 0°C and normal atmospheric pressure.

$$n_o = (2.68719 \pm 0.0001) \times 10^{19}\ cm^{-3}$$

Magnetic field due to a current : The intensity of the magnetic field in oersted at the center of a circular conductor of radius r in which a current I in absolute electromagnetic units is flowing,

$$H = \frac{2\pi I}{r}$$

If the circular coil has n turns the magnetic intensity at the center is,

$$H = \frac{2\pi n I}{r}$$

The magnetic field in a long solenoid of n turns per centimeter carrying a current I in absolute electromagnetic units

$$H = 4\pi n I$$

If I is given in amperes the above formulae become, —

$$H = \frac{2\pi I}{10r}, \quad H = \frac{2\pi n I}{10r}.$$

$$H = \frac{4\pi n I}{10}$$

Magnetic field intensity or magnetizing force : is measured by the force acting on unit pole. Unit field intensity, the oersted, is that field which exerts a force of one dyne on unit magnetic pole. The field intensity is also specified by the number of lines of force intersecting unit area normal to the field, equal numerically to the field strength in oersted. Magnetizing force is measured by the space rate of variation of magnetic potential and as such its unit may be the *gilbert per centimeter*. The gamma (γ) is equivalent to 0.00001 oersted.

Magnifying power of an optical instrument is the ratio of the angle subtended by the image of the object seen through the instrument to the angle subtended by the object when seen by the unaided eye. In the case of the microscope or simple magnifier the object as viewed by the unaided eye is supposed to be a distance of 25 cm (10 in.).

Mass by weighing on a balance with unequal arms : If W_1 is the value for one side, W_2 the value for the other, the true mass,

$$W = \sqrt{W_1 W_2}.$$

Mixtures : consist of two or more substances intermingled with no constant percentage composition, and with each component retaining its essential original properties.

Mole : Mass numerically equal to the molecular weight. It is most frequently expressed as the gram molecular weight, i.e., as the weight of one mole expressed in grams.

Molecular weight : The sum of the atomic weights of all the atoms in a molecule.

Molecule : The smallest unit quantity of matter which can exist by itself and retain all the properties of the original substance.

Moment of force or torque: The effectiveness of a force to produce rotation about an axis, measured by the product of the force and the perpendicular distance from the line of action of the force to the axis. Cgs unit — the dyne-centimeter. If a force F acts to produce rotation about a center at a distance d from the line in which the force acts, the force has a torque,

$$L = Fd.$$

Neutralization is a reaction in which the hydrogen ion of an acid and the hydroxyl ion of a base unite to form water, the other product being a salt.

Neutron: A neutral elementary particle of mass number 1. It is believed to be a constituent particle of all nuclei of mass number greater than 1. It is unstable with respect to beta-decay, with a half life of about 12 minutes. It produces no detectable primary ionization in its passage through matter, but interacts with matter predominantly by collisions and, to a lesser extent, magnetically. Some properties of the neutron are: rest mass, 1.00894 atomic mass unit; charge, 0; spin quantum number, ½; magnetic moment, 1.9125 nuclear Bohr magnetrons.

Newton: The force necessary to give acceleration of one meter per second per second to one kilogram of mass.

Newton's law of cooling: The rate of cooling of a body under given conditions is proportional to the temperature difference between the body and its surroundings.

Newton's law of motion:

I. Every body continues in its state of rest or of uniform motion in a straight line except in so far as it may be compelled to change that state by the action of some outside force.

II. Change of motion is proportional to force applied and takes place in the direction of the line of action of the force.

III. To every action there is always an equal and opposite reaction.

Nucleus: The dense central core of the atom, in which most of the mass and all of the positive charge is concentrated. The charge on the nucleus, an integral multiple of Z of the electronic charge, is the essential factor which distinguishes one element from another. Z is called the atomic number and gives the number of protons in the nucleus, which includes a roughly equal number of neutrons. The mass number A gives the total number of neutrons plus protons.

Ohm's law: Current in terms of electromotive force E and resistance R.

$$I = \frac{E}{R}$$

The current is given in amperes when E is in volts and R in ohms.

Pascal's law: Pressure exerted at any point upon a confined liquid is transmitted undiminished in all directions.

Pendulum: For a simple pendulm of length L, for a small amplitude, the complete period,

$$T = 2\pi \sqrt{\frac{l}{g}} \quad \text{or} \quad g = 4\pi^2 \frac{l}{T^2}$$

T will be given in seconds if L is in cm and g in cm per sec^2. For a sphere suspended by a wire of negligible mass where d is the distance from the knife edge to the center of the sphere whose radius is r, the length of the equivalent simple pendulum,

$$L = d + \frac{2r^2}{5d}$$

If the period is P for an arc θ, the time of vibration in an infinitely small arc is approximately

$$T = \frac{P}{1 + \frac{\sin^2 \theta}{4}}$$

For a compound pendulum, if a body of mass m be suspended from a point about which its moment of inertia is I with its center of gravity a distance h below the point of suspension, the period

$$T = 2\pi\sqrt{\frac{I}{mgh}}$$

Power : The time rate at which work is done. Units of power, - the watt, one joule (ten million ergs) per second, the kilowatt is equal to 1000 watts; the horse-power, 33,000 foot-pounds per minute, is equal to 746 watts.

If an amount of work W is done in time t the power or rate of doing work is

$$P = \frac{W}{t}$$

Power will be obtained in watts if W is expressed in joules (10^7 ergs) and t in seconds.

Pressure : Force applied to, or distributed over, a surface; measured as force per unit area. Cgs unit, – the barye, one dyne per square centimeter. The megabarye is equal 10^6 dynes per square centimeter. Pressure is also measured by the height of the column of mercury or water which it supports.

The pressure due to a force F distributed over an area A,

$$P = \frac{F}{A}$$

Absolute Pressure : Pressure measured with respect to zero pressure.

Gauge Pressure : Pressure measured with respect to that of the atmosphere.

Projectiles : For bodies projected with velocity v at an angle a above the horizontal, the time to highest point of flight.

$$t = \frac{v \sin a}{g}$$

Total time of flight to reach the original horizontal plane,

$$T = \frac{2v \sin a}{g}$$

Maximum height, $h = \dfrac{v^2 \sin^2 a}{2g}$

Horizontal range, $R = \dfrac{v^2 \sin 2a}{g}$

In the above equations the resistance of the air is neglected. g is the acceleration due to gravity.

Proton : An elementry particle having a positive charge equivalent to the negative charge of the electron but possessing a mass approximately 1837 times as great. The proton is in effect the positive nucleus of the hydrogen atom.

Radiation : The emission and propagation of energy through space or through a material medium in the form of waves.

The term may be extended to include streams of sub-atomic particles as alpha-rays, beta-rays and cosmic rays as well as electromagnetic radiation. Often used to designate the energy alone without reference to its character. In the case of light this energy is transmitted in bundles (photons).

Reduction is any process which increases the proportion of hydrogen or base-forming elements or radicals in a compound. Reduction is also the gaining of electrons by an atom, an ion, or an element thereby reducing the positive valence of that which gained the electron.

Relative humidity : The ratio of the quantity of water vapor present in the the atmosphere to the quantity which would saturate at the existing temperature. It is also the ratio of the pressure of water vapor present to the pressure of saturated water vapor at the same temperature.

Resistance is a property of conductors depending on their dimensions, material and temperature which determines the current produced by a given difference of potential. The practical unit of resistance is the **ohm**, that resistance through which a difference of potential of one volt will produce a current one ampere. The **international ohm** is the resistance offered to an unvarying current by a column of mercury at 0°C, 14.4521, grams in mass, of constant cross-sectional area and 106.300 centimeters in length, sometimes called the legal ohm.

Resistance of conductors in series and parallel : The total resistance of any number of resistances joined in series is the sum of the separate resistances. The total resistance of conductors in parallel whose separate resistances are $r_1, r_2, r_3, \dots r_n$ is given by the formula

$$\frac{1}{R} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} \dots + \frac{1}{r_n}$$

when R is the total resistance. For two terms this becomes,

$$R = \frac{r_1 r_2}{r_1 + r_2}$$

Salt : Any substance which yields ions other than hydrogen or hydroxyl ions. A salt is obtained by displacing the hydrogen of an acid by a metal.

Sensitiveness of a balance : Assuming the three knife edges of a balance to lie on a straight line,—if M is the weight of the beam, h the distance of the center of gravity below the knife edge, L the length of the balance arms and m a small mass added to one pan, the deflection θ produced is given by

$$\tan \theta = \frac{mL}{Mh}$$

Simple machine : A contrivance for the transfer of energy and for increased convenience in the performance of work.

Mechanical advantage is the ratio of the resistance overcome to the force applied. Velocity ratio is the ratio of the distance through which force is applied to the distance through which resistance is overcome.

Efficiency is the ratio of the work done by a machine to the work done upon it.

If a force f applied to a machine through a distance S results in a force F exerted by the machine through a distance s, neglecting friction,

$$fS = Fs.$$

The theoretical mechanical advantage or velocity ratio in the above case is,

$$\frac{S}{s}$$

Actually the force obtained from the machine will have a smaller value than will satisfy the equation above. If F, be the actual force obtained, the practical mechanical advantage will be,

$$\frac{F'}{f}$$

The efficiency of the machine,

$$E = \frac{F's}{fS}$$

Snell's law of refraction: If i is the angle of incidence, r the angle of refraction, v the velocity of light in the first medium, v' the velocity in the second medium, the index of refraction n,

$$n = \frac{\sin i}{\sin r} = \frac{v}{v'}$$

Solubility of one liquid or solid in another is the mass of a substance contained in a solution which is in equilibrium with an excess of the substance. Under these conditions the solution is said to be saturated. Solubility of a gas is the ratio of concentration of gas in the solution to the concentration of gas above the solution.

Solubility product or precipitation value is the product of the concentrations of the ions of a substance in a saturated solution of the substance. These concentrations are frequently expressed as moles of solute per liter of solution.

Solute: That constituent of a solution which is considered to be dissolved in in the other, the solvent is usually present in larger amount than the solute.

A true solution is a mixture, liquid, solid or gaseous, in which the components are uniformly distributed throughout the mixture. The proportion of the constituents may be varied within certain limits.

Solvent: That constituent of a solution which is present in larger amount ; or the constituent which is liquid in the pure state, in the case of solutions of solids or gases in liquids.

Specific Gravity: The ratio of the mass of a body to the mass of an equal volume of water at 4°C or other specified temperature.

Specific Heat of a substance is the ratio of its thermal capacity to that of water at 15°C.

If a quantity of heat H calories is necessary to raise the temperature of m grams of a substance from t_1 to t_2°C, the specific heat or more properly, thermal capacity of the substance,

$$s = \frac{H}{m(t_2 - t_1)}$$

Specific heat by the method of mixtures: Where a mass m_1 of the substance is heated to a temperature t_1, then placed in a mass of water m_2 at a temperature t_2 contained in a calorimeter c, t_3 the final temperature.

$$m_1 s (t_1 - t_3) = m_3 c + m_2 (t - t_2).$$

Black's ice calorimeter : If a body of mass m and temperature t melts a mass m' of ice, its temperature being reduced to 0°C, the specific heat of the substance is,

$$s = \frac{80\ 1m'}{mt}$$

Bunesn's ice calorimeter : A body of mass m at temperature t causes a motion of the mercury column of l centimeters in a tube whose volume per unit length is v. The specific heat is

$$s = \frac{884\, lv}{mt}$$

Stress : The force producing or tending to produce deformation in a body measured by the force applied per unit area Cgs units,—one dyne per square centimeter.

Surface tension : Two fluids in contact exhibit phenomena due to molecular attractions which appear to arise from a tension in the surface of separation. It may be expressed as dynes per cm or as ergs per square centimeter.

The total force along a line of length l on the surface of a liquid whose surface tension is T,

$$F = lT.$$

Capillary tubes : If a liquid of density d rises a height h in a tube of internal radius r the surface tension is,

$$T = \frac{rhdg}{2}$$

The tension will be in dynes per cm if r and h are in cm, d in gm per cm^3 and g in cm per sec^2.

Drops and bubbles : Pressure in dynes per cm^2 due to surface tension on a drop of radius r cm for a liquid whose surface tension is T dynes per cm,

$$P = \frac{2T}{r}$$

For a bubble of mean radius r cm,

$$P = \frac{4T}{r}$$

Temperature may be defined as the condition of a body which determines the transfer of heat to or from other bodies. Particularly, it is a manifestation of the average translational kinetic energy of the molecules of a substance due to heat agitation.

Thermal expansion : The coefficient of linear expansion or expansivity is the ratio of the change in length per degree C to the length at 0°C. The coefficient of volume expansion (for solids) is approximately three times the linear coefficient. The coefficient of volume expansion for liquids is the ratio of the change in volume per degree to the volume at 0°C. The value of the coefficient varies with temperature. The coefficient of volume expansion for a gas under constant pressure is nearly the same for all gases and temperatures and is equal to 0.00367 for 1°C.

If l_0 is the length at 0°C, α the coefficient of linear expansion, the length at t°C is,

$$l_t = l_0\,(l + \alpha t)$$

General formula for thermal expansion : The rate of thermal expansion varies with the temperature. The general equation giving the magnitude m_t (length or volume) at a temperature t where m_0 is the magnitude at 0°C is

$$m_t = m_0\,(1 + \alpha t + \beta t^2 + \gamma t^3 \ldots)$$

where α, β, γ, etc. are empirically determined coefficients.

Volume expansion: If V represents volume and β the coefficient of expansion,

$$V_t = V_0 (1 + \beta t).$$

for solids

$$\beta = 3\alpha \text{ (approximately)}.$$

Thermodynamics, law of :

I. When mechanical work is transformed into heat or heat into work, the amount of work is always equivalent to the quantity of heat.

II. It is impossible by any continuous self-sustaining process for heat to be transferred from a colder to a hotter body.

Time, unit of : The fundamental invariable unit of time is the ephemeris second, which is defined as 1/31,556, 925. 9747 of the tropical year for 1900 January 0^d12^h ephemeris time. The ephemeris day is 86,400 ephemeris seconds.

The former unit of time was the mean solar second, defined as 1/86,400 of the mean solar day.

Triangle or polygon of forces: If three or more forces acting on the same point are in equilibrium, the vectors representing them form, when added, a closed figure.

Uniformly accelerated rectilinear motion: If v_0 is the initial velocity, v_t the velocity after time t, the acceleration,

$$a = \frac{v_t - v_0}{t}$$

The velocity after time t,

$$v_t = v_0 + at$$

Space passed over in time t,

$$s = v_{0t} + \tfrac{1}{2}at^2$$

Velocity after passing over space s,

$$v = \sqrt{v_0^2 + 2as}$$

Space passed over in the nth second

$$s = v_0 + \tfrac{1}{2}a(2n-1).$$

In the above and following similar equations the values of the space, velocity, and acceleration must be substituted in the same system. For space in cm, velocity will be in cm per sec. and acceleration in cm per sec.

Valence of an atom of an element is that property which is measured by the number of atoms of hydrogen (or its equivalent) one atom of that element can hold in combination if negative, or can displace in a reaction if it is positive.

Vapor : The words **vapor** and **gas** are often used interchangeably. **Vapor** is more frequently used for a substance which, through present in the gaseous phase, generally exists as a liquid or solid at room temperature. **Gas** is more frequently used for a substance that generally exists in the gaseous phase at room temperature. Thus one would speak of iodine or carbon tetrachloride vapors and of oxygen gas.

Vapor pressure : The pressure exerted when a solid or liquid is in equilibrium with its own vapor. The vapor pressure is a function of the substance and of the temperature.

Velocity: Time rate of motion in a fixed direction. Cgs units,—one centimeter per second.

If s is space passed over in time t, the velocity,

$$v = \frac{s}{t}$$

Volt: The unit of electromotive force. It is the difference in potential required to make a current of one ampere flow through a resistance of one ohm.

Weight: The force with which a body is attracted toward the earth. Cgs unit,—the dyne.

Although the weight of a body varies with its location, the weights of various standards of mass are often used as units of force as,—pound weight, or pound force, gram weight, etc. The weight of mass m, where g is the acceleration due to gravity,

$$W = mg$$

The weight will be given in dynes when m is in grams and g in cm per sec^2.

Wheatstone's bridge: If the resistance r_1, r_2, r_3, and r_4 form the arms of a Wheatstone's bridge in order as circuit (omitting cell and galvanometer connections) is traced, when the bridge is balanced,

$$\frac{r_1}{r_2} = \frac{r_4}{r_3} \quad \text{or} \quad \frac{r_1}{r_4} = \frac{r_2}{r_3}$$

Work: When a force acts against resistance to produce motion in a body the force is said to do work. Work is measured by the product of the force acting and the distance moved through against the resistance. Cgs units of work,—the erg, a force of one dyne acting through a distance of one centimeter. The joule is 1×10^7 ergs. The footpound is the work required to raise a mass of one pound a vertical distance of one foot where $g = 32.174$ ft./sec^2. The footpoundal is the work done by a force of one poundal acting through a distance of one foot. The International joule, a unit of electrical energy, is the work expended per second by a current of one International ampere flowing through one International ohm. The kilowatt-hour is the total amount of energy developed in one hour by a power of one kilowatt.

If a force F acts through a space s, the work done is

$$W = Fs$$

Work will be given in ergs if F is in dynes and s in cm.

Work done in rotation. If a torque L dyne–cm acts through an angle θ radians, the work done in ergs is

$$W = L\theta$$

ACOUSTICAL UNITS AND DEFINITIONS

Pressure: The unit of sound pressure is the dyne/cm^2, usually quoted as the root mean square (r.m.s.) pressure for a pure sinusoidal wave.

Frequency: The unit of frequency is the cycle per second (c/s).

Threshold of hearing is for a normal (average) observer, the sound level or intensity which is just audible. For a pure sinusoidal note of frequency 1000 c/s it is close to a root mean square pressure of 0.0002 dyne/ cm^2.

Reverberation in an enclosure is the persistence of sound due to multiple reflections from the walls, etc. of the enclosure.

Absorption coefficient of a surface is the sound energy absorbed to the total sound energy incident on the surface. The ideal absorber is one from which no sound is reflected or scattered. For unit area of various substances, the coefficient is expressed in terms of equivalent area of open window (diffraction effects excluded). Unit, ft^2 of open window or Sabine. The coefficient varies with frequency.

HEAT UNITS AND DEFINITIONS

Temperature (*t* **or** *T*): Degree of hotness usually measured on an arbitrary scale with an arbitrary zero. The common scales of temperature are the Celsius (or centigrade) scale, the Fahrenheit scale and the Reaumur scale. The zero of the Celsius and Reaumur scales is the freezing point of water, while that of the Fahrenheit scale is the temperature of a mixture of common salt and ice.

Freezing point of water :

Celsius (centigrade)	0° C
Fahrenheit	32° F
Reaumur	0° R

Boiling point of water :

Celsius (centigrade)	100° C
Fahrenheit	212° F
Reaumur	80° R

The Kelvin or Absolute scale has as its zero the lowest attainable temperature while the size of the degree is the same as that on the Celsius (centigrade) scale. The Absolute scale is that given by the theoretical Carnot heat engine and is identical with the perfect gas scale. Absolute zero, 0°K is – 273.15°C.

Heat : A form of energy. The unit of heat is the calorie (cal), i.e., the amount of heat necessary to raise the temperature of 1 gm of water by 1°C. However, this quantity is not constant. It depends on the initial temperature of the water and we define the 15° calorie as the heat required to raise the temperature of 1 gm of water from 14.5° to 15.5 C. The mean calorie is defined as one hundredth of the heat required to raise the temperature to 1 gm of water from 0° to 100° C. To remove the inconvenience of these definitions, it has been proposed that the calorie be abandoned and the joule substituted as the unit of heat energy. This recommendation has not yet been generally adopted.

NOTE : **1 calorie=** $\frac{3600}{860}$ joules 4.186 joules.

British thermal unit (B.Th.U.) = Heat required to raise 1 lb of water 1°F= 252.0 cal.

Centigrade heat unit (C. H. U.) : Heat required to raise 1 lb of water 1°C= 453.6 cal.

One therm : = 100,000 B. Th. U.

1 kilocalorie or Calorie: =1000 calories and is defined as the heat required to raise the temperature of 1 kg of water 1°C.

Specific heat : Ratio of heat required to raise the temperature of 1 gm of a substance 1°C, to that required to raise the temperature of 1 gm of water 1°C. Alternatively, it is the number of calories required to raise the temperature of 1 gm of substance by 1°C.

Heat capacity : The amount of heat required to raise the temperature of a body 1°C.

Water equivalent is the number of grams of water having the same heat capacity as the given body.

Thermal conductivity (k) is the heat flowing per second between two parallel faces of unit area of a block of material when the faces are unit distance apart and are maintained at a temperature difference of 1 degree with all the heat entering one face leaving by the opposite face.

Latent heat of $\left\{\begin{matrix}\textbf{fusion}\\ \textbf{vaporisation}\end{matrix}\right\}$ is the amount of heat required to convert 1 gm of the substance, at its $\left\{\begin{matrix}\text{melting point}\\ \text{boiling point}\end{matrix}\right\}$ into $\left\{\begin{matrix}\text{liquid}\\ \text{vapour}\end{matrix}\right\}$ at the same temperature.

Coefficient of $\left\{\begin{matrix}\textbf{linear}\\ \textbf{cubical}\end{matrix}\right\}$ **expansion** of a substance is the increase in $\left\{\begin{matrix}\text{length}\\ \text{volume}\end{matrix}\right\}$ per unit $\left\{\begin{matrix}\text{length}\\ \text{volume}\end{matrix}\right\}$ per degree rise of temperature.

Critical temperature of a gas or vapour is that temperature above which it is not possible to liquify the gas by the application of presssure alone. To liquify a gas it must be cooled below its critical temperature before being compressed.

Critical pressure is that pressure with just liquifies a gas at its critical temperature.

Critical volume is the volume of unit mass of gas at its critical temperature and pressure, i.e., it is the reciprocal of the critical density. It is often taken as the volume of one gram molecule of a gas as its critical temperature and pressure.

MOMENTS OF INERTIA

M = mass of body

Body	Axis of Oscillation	Moment of Inertia
Uniform thin rod (length $= l$)	At end, perpendicular to length.	$M\frac{l^2}{3}$
Uniform thin rod (length $= l$)	At middle, perpendicular to length.	$M\frac{l^2}{12}$
Rectangular lamina (sides a and b)	Through centre of gravity parallel to side b	$M\frac{a^2}{12}$
Rectangular lamina (sides a and b)	Through centre of gravity perpendicular to plane	$M\frac{a^2+b^2}{12}$
Rectangular solid sides a, b and c)	Through centre of gravity perpendicular to face ab	$M\frac{a^2+b^2}{12}$
Circular lamina (radius $= r$)	Any diameter	$M\frac{r^2}{4}$
Circular lamina (radius $= r$)	Through centre perpendicular to plane	$M\frac{r^2}{2}$
Right circular cylinder (radius $= r$)	Axis of figure	$M\frac{r^2}{2}$
Hollow cylinder (external radius $= R$, internal radius $= r$)	Axis of figure	$M\frac{R^2+r^2}{2}$
Right circular cylinder (length $= l$, radius $= r$)	Through centre perpendicular to axis of figure	$M\left(\frac{l^2}{12}+\frac{r^3}{4}\right)$
Sphere (radius $= r$)	Any diameter	$M\frac{2r^2}{5}$
Hollow sphere (external radius $= R$, internal radius $= r$)	Any diameter	$M\left(\frac{2}{5}\frac{R^5-r^3}{R^3-r_3}\right)$

PHOTOMETRIC AND OPTICAL UNITS AND DEFINITIONS

Luminous intensity : The unit of light still widely employed is the candle, defined (1860) in terms of the light energy emitted per second in all directions by a specified sperm wax candle burning uniformly and consuming wax at a known rate, but since 1909 defined in terms of the light emitted per second in all directions from specified electric lamps. Since 1921 the unit has been known as the International Candle. A new unit, the candela (cd), has recently been adopted internationally (1945, 1948). It is defined as 1/60th of the light emitted per cm^2 per second by a black body at the freezing point of platinum. 1 candela = 0.982 international candles.

Luminous flux : The unit of luminous flux, the lumen (lm) is defined as the light energy emitted per second within unit solid angle by a uniform point source of unit luminous intensity.

Thus $4\pi \times$ (luminous flux) = luminous intensity.

Unit solid angle, 1 steradian, is the solid angle subtended at the centre of a sphere of unit radius by unit area on the surface of the sphere.

Illumination of a surface is defined as the luminous flux reaching it perpendicularly per unit area. The British unit is the lumen/ft^2, formerly called the foot candle (f.c.). The metric unit is the lumen/m^2 or lux (lx).

Lambert's cosine law for a surface receiving light obliquely, the illumination is proportional to the cosine of the angle which the light makes with the normal to the surface.

Brightness of a surface is that property by which the surface appears to emit more or less light in the direction of view. This is a subjective quantity. The corresponding physical measurement of the light actually emitted is called the luminance.

Luminance of a surface is the light actually emitted (ie., the luminous intensity) per unit projected area of surface, the plane of projection being perpendicular to the direction of view. Unit, candle/ft^2 or candle/ m^2. In engineering the luminance of an ideally diffusing surface emitting or reflecting one lumen / ft^2 is called one foot–lambert (ft–L). An ideal diffuser of luminance 1 candle/ft^2 in all directions emits $= \pi$ lumens/ft^2.

The velocity of light $= 2.998 \times 10^{10}$ cm/sec = 186,300 miles/sec in vacuum.

One angstrom unit is the unit in which the wavelengths of light are measured 1 Å $= 10^{-8}$ cm.

Refractive index of a material (μ) is the ratio of the velocity of light in free space to that in the material.

Snell's law : For light incident on a boundary between two media, the ratio of the sine of the angle of incidence (the angle between the light ray in the first medium and the normal to the boundry surface) to the sine of the angle of refraction (the angle between the refracted ray in the second medium and the normal) is a constant, being equal to the inverse ratio of the refractive indices of the two media.

One dioptre is the unit of measure of the power of a lens and is given numerically by the reciprocal of the focal length expressed in metres.

RELATIONS BETWEEN THE SYSTEMS OF UNITS

Unit	Equal to	Reciprocal
Length		
1 inch	2.540 cm	0.3937
1 yard	0.91439141 m	1.093615
1 mile	8km = 5 miles (approx)	
Area		
1 in^2	6.452 cm^2	0.1550
1 ft^2	0.09290 m^2	10.764
1 yd^2	0.8361 m^2	1.196
1 mile^2	2.590 km^2	0.3861
Volume		
1 in^3	16.39 cm^3	0.06102
1 ft^3	28.32 liters	0.03531
	0.02832 m^3	35.314
1 yd^3	0.764553 m^3	1.30795
1 gallon	4.546 liters	0.2200
1 gallon (U.S.A.)	0.004546 m^3	220.0
	277.42 in^1 (in U.K.)	.003606
	231 in^3	0.004329
	3.785332 liter	
Mass		
1 oz (avoir)	28.35 g	0.03527
1 lb (av)	0.4535923 kg	2. 204623
	7000 grains (Troy)	0.0001429
1 ton	1016 kg	0.0009842
Density		
1 lb/ft	0.01602 g/cm^3	62.43
	16.02 kg/m^3	0.06243

Unit	Equal to	Reciprocal
Force		
1 poundal	13825 dynes	7.233×10^{-5}
	0.13825 newtons	7.233
*1 lb (ie the wt of 1 lb mass)	4.448×105 dynes	2.248×10^{-6}
	4.448 newtons	0.2248
1 newton	10^5 dynes	10^{-5}
Pressure		
1 lb/in	68948 dynes/cm^2	1.450×10^{-5}
	70.31 g/cm^2	0.01422
	703.1 kg/m^2	0.001422
	6894.8 newtons/m^2	1.45×10^{-4}
Energy		
1 foot poundal	0.04214 joules	23.73
1 ft lb	1.356 joules	0.7375
1 kilowatt-hour	1 Board of Trade unit of electrical energy	
	3.6×10^6 joules	0.2778×10^{-6}
Power		
1 horse power	0.746 kilowatts	1.34
	550 ft lbs/ sec.	0.001818
Electrical		
1 ampere	0.1 e.m.u. of current strength	
	3×10^9 e.s.u. of current (rate of passage of charge)	
1 volt	10^8 e.m.u. of potential difference	
	1/300 e.s.u. of potential difference	
1 ohm	10^9 e.m.u. of resistance	
	1.11×10^{-11} e.s.u. of resistance	
1 coulomb	0.1 e.m.u. of charge (quantity) 3×10^9 e.s.u. of quantity	
1 farad	10^{-9} e.m.u. of capacitance 3×10^{11} e.s.u. of capacitance	
1 henry	10^9 e.m. of inductance	
	1.11×10^{-11} e.s u. of inductance	
Magnetic		
1 weber/m^2	10^4 gauss	
1 ampere/metre	$4\pi \times 10^{-3}$ c. g. s. oersteds	
1 weber	10^8 maxwells	
1 M.K.S. pole	$\frac{10^8}{4\pi}$ c.g.s. poles	

Unit	Equal to	Reciprocal
Miscellaneous		
1 degree	0.01745 radians	57.296
1 kilocalorie	3.968 lb–degrees F	0.2520
1 lb water at 620° F	0.4546 litres	2.200
	101000 gallons	10.00
1 lb water at 4° C	0.01602 ft^3	62.43
1 standard atmosphere	14.70 lb/in^2	0.06805
	1013250 $dynes/cm^2$	0.9869×10^{-6}
	760 mm of mercury	0.1314×10^{-2}
1 mile/hour	1.467 ft/sec	0.6818
	44.70 cm/sec	0.02237
Standard acceleration of gravity	980.695 cm/sec.	
	32.1741 ft/sec	
1 gram-molecule (mole) of any gas	22.42 litres at N.T.P.	
1 litre air at N.T.P.	1.293 gm	
1 knot	1 nautical mile per hour	= 6082.66 ft/hr
1 Admiralty knot	6080 ft/hr	

Length

1 mil = 0.001 inch = 25.4001 microns = 0.254001 millimeter
1 hand = 4 inches = 100.600 centimeters
1 span = 9 inches = 22.86005 centimeters
1 fathom (fath.) = 6 feet = 1.828804 meters
1 link (li.) = 0.66 foot = 7.93 inches = 20.11684 centimeters
1 rod (rd.) = 25 links = 5.029210 meters
1 surveyor's or Gunter's chain (ch.) = 4 rods = 100 links = 66 feet = 50.11684 meters
1 engineer's or Ransden's chain = 100 links of one foot each = 100 feet = 30·480 meters
International nautical mile— 1.151 statute miles = 1,852 meters = 6,076·10333 feet of arc on the Earth's surface at the equator.
1 British yard = 3 feet = 36 inches = 0.914399 meter
1 British inch = 2.539998 centimeters
1 British mile = 1,760 yards = 1.60934 kilometers
1 furlong (fur.) = 40 rods = 220 yards = 660 feet = 201.168 meters
1 pole (British) = 5.5 yards = 5.0292 meters = approximately 1 rod
1 British fathom = 6.00 feet
1 toise = 6 Paris feet = 1.94904 meters
1 Paris foot (pied) = 12 Paris inches = 0.324839 meter
1 Paris inch (pouce) = 12 Paris lines = 2.70700 centimeters
1 Paris line (ligne) = 0.225583 centimeter
1 light year = 5.9×10^{12} miles = 9.5×10^{12} kilometers

1 point (type sizes) = 1/72 or 0.01389 inch
1 line = 1/12 or 0.083333 inch
1 cubit = 18 inches
1 U.S. mile = 320 rods = 1,760 yards = 5,280 feet = 63,360 inches
10 meters = 1.98838 rods
1 Angstrom (A) = 3.93700×10^{-9} inch
1 micron (M) = 3.93700×10^{-5} inch

Apothecaries' fluid system

1 fluid ounce = 1.80469 cubic inches
1 gallon = 128 fluid ounces = 8 pints
1 British Imperial gallon = 8 pints = 160 fluid ounces = 4.5459631 liters
1 British fluid ounce = 8 drachms = 28.4130 cubic centimeters
1 British fluid drachm = 60 minims = 3.5515 cubic centimeters
1 British minim = 0.059194 cubic centimeter.

Mass

NOTE :

Three systems are in use,–avoirdupois, troy and apothecaries'.
The grain is the same in all.

Avoirdupois–commercial-U. S. system

The U.S Standard pound avoirdupois is defined as 453.5924277 grams

1 pound avoirdupois in the mass of 27.692 cubic inches of water weighed in air at 40° C, 760 mm pressure
1 short hundred weight (cwt) = 100 pounds = 45.359243 kilograms
1 short ton = 20 short hundred weight = 2,430.56 troy pounds = 907.18486 kilograms
1 stone (British) = 14 pounds = 6.350 kilograms
1 quarter (British) = 28 pounds = 12.70 kilograms
1 long hundredweight (British) = 4 quarters =112 pounds = 50.802352 kilograms
1 long ton (British) = 20 long hundred weight = 1,016.04704 kilograms
1 long ton = 1.12000 short tons = 2,722.22 troy pounds 1.01605 metric tons
1 short ton = 0.892857 long ton = 29,166.66 troy or apothecaries' ounces = 0.907185, metric ton
1 avoirdupois pound = 5.21528 troy or apothecaries' pounds = 14.5833 troy ounces
1 avoirdupois ounce = 0.911458 troy or apothecaries' ounce

Volume

1 board foot (bd.ft) = 144 cubic inches = 2,359.8 cubic centimeters
1 cord = 128 cubic feet = 3.625 cubic meters
1 British cubic foot = 1,728 cubic inches = 0.083168 cubic meter

1 British cubic yard = 27 cubic feet = 0.764553 cubic meter
1 cubic foot = 6.229 British gallons = 7.481 U.S. gallons
1 cubic yard = 168.17 British gallons

Mass - metric system

1 kilogram = 15,432.35639 grains = 0.00110231 short ton = 0.00098421 long ton
1 metric carat = 200 milligrams = 3.0864712 grains
1 myriagram = 10,000 grams = 10 kilograms = 22.04622 pounds avoirdupois
1 quintal (metric) = 100 kilograms = 22.04622 pounds avoirdupois
1 millier or tonne = 1,000 kilograms = 2,204.622 pounds avoirdupois = 2,679.229 pounds troy = 0.98423640 long ton = 1.1023112 short tons

Capacity

One liter is the volume of pure water at 40°C and 760 mm pressure which weighs 1 kilogram.

1 liter = 1.000027 cubic decimeter = 1000.027 cm^3 = 270.518 fl. drams = 33.8147 fl. ounces
1 ml = 16.2311 minims = 0.0610250 cu inches
1 liter = 1.05671 liq. quarts = 0.264178 gallons = 1.81620 dry pints = 0.908102 dry quarts = 0.113513 pecks = 0.0283782 bushel

U. S. System-Liquid Measure

1 gill = 4 fluid ounces = 1.18292 deciliters
1 gallon (U. S.) of water at 15° weighs about 8.337 pounds avoirdupois or 3.7880 kilograms = 0.83268 British gallon
1 hogshead = 63 gallons
1 firkin = 9 gallons = 34.06799 liters
1 tun = 252 gallons
1 British gill = 1.4206 deciliters
1 British pint = 4 gills = 0.56825 liter
1 British quart = 2 pints = 1.13650 liters
1 British gallon = 4 quarts = 277.420 cubic inches = 0.16054 cubic foot = 4.5459631 liters
1 British gallon of water at 15° C weighs 10 pounds = 1.20094 U. S. gallons

DECIMAL EQUIVALENTS OF COMMON FRACTIONS

	1/32	2/64	=	0.03125		17/32	34/64	=	0.53125
1/16	2/32	4/64	=	.0625	9/16	18/64	36/64	=	.5625
	2/32	6/64	=	.09375		19/32	38/64	=	.59375
1/8	4/32	8/64	=	.125	5/8	20/32	40/64	=	.625
	5/32	10/64	=	.15625		21/32	42/64	=	.65625

3/16	6/32	12/64	=	.1875	11/16	22/32	44/64	=	.6875
	7/32	14/64	=	.21875		23/32	46/64	=	.71875
1/4	8/32	16/64	=	.25	3/4	24/32	48/63	=	.76
	9/32	18/64	=	.28125		25/32	50/64	=	.78125
5/16	10/32	20/64	=	.3125	13/16	26/32	52/64	=	.8125
	11/52	22/64	=	.34375		27/32	54/64	=	.84375
3/8	12/32	24/64	=	.375	7/8	28/38	56/64	=	.875
	13/32	26/64	=	.04625		29/32	58/64	=	.90625
7/16	14/32	28/64	=	.4375	15/16	30/32	60/64	=	.9375
	15/32	30/64	=	.46875		31/32	62/64	=	.96875
51/2	16/32	32/64	=	.50					

MISCELLANEOUS CONSTANTS

Equatorial radius of the earth, 6378.388 km; 3963.34 miles (statute).

Polar radius of the earth, 6356.918 km; 3946.99 miles (statute).

1 degree of latitude at 40° = 69 miles

1 international nautical mile = 1.15078 miles (statute)=1852 meters = 6080 feet.

Mean density of the earth, 5.522 gm/cm^3, 344.7 lb ft^3

Constant of gravitation,. 6.673 $\pm$ 0.003 $\times$ 10^{-8} cm^3/gm sec^2.

Acceleration due to gravity at sea level, latitude 45°
980.621 cm sec^2 = 32.1715 ft/sec^2.

Length of seconds pendulum at sea level, latitude 45°.
99.35771 cm = 39.1171 in.

1 knot (international) = 101 289 ft/min = 1.6878 ft/sec=1.1508 miles (statute)/ hr

1 micron = 10^{-4}mm.

1 Angstrom unit = 10^{-8} cm.

Mass of hydrogen atom (1.67339 $\pm$ 0.00031) $\times$ 10^{-24} gm.

Avogadro's number (physical) (6.02486 $\pm$ 0.00061) $\times$ 10^{-23} per gram mole.

Avogadro's number (chemical) (6.02322 $\pm$ 0.00016) $\times$ 10^{-23} per gram mole.

Plancks constant (6.62517 $\pm$ 0.00023) $\times$ 10^{-27} erg-sec.

Density of mercury 0° C = 13.5955 gm/cm^3.

Density of water, maximum at 3.98° C = 0.999973 gm/cm^3

Density of air, 0° C at 760 mm = 1.2929 gm/liter.

Velocity of sound in dry air, 0° C., 331.36 m/sec = 1087.1 ft/sec.

Velocity of light in vacuum = (2.99793 $\pm$ 0.000004) $\times$ 10^{10} cm/sec.

Heat of fusion of water at 0°C, 79.71 cal/gm

Heat of vaporization of water, 100° C, 539.55 cal/gm.

Electrochemical equivalent of silver, 0.001118 g/sec international ampere.

THE EARTH

Polar radius=6357 km=3951 miles.
Equatorial radius=6378 km=3964 miles.
Mean radius=6371 km=3960 miles
Mass=5.980 × 10^{27} gm=5.886 × 10^{21} tons.
1° of latitude at equator=110.5 km=68.70 miles.
1° of latitude at poles=111.7 km=69.41 miles.
1° of longitude at equator=111.3 km=69.17 miles.
Inclination of equator to ecliptic=23° 27'.
Greatest height (Mt.Everest)=29,028 ft (1954 Indian Survey).
Greatest depth—Mindanao Deep (east of the Philippines) 10,854 m=35,610 ft.
Land area=148.8 × 10^6 km^2=5.747 × 10^7 miles^2.
Ocean area=361.3 × 10^6 km^2=13.95 × 10^7 miles^2.

Principal Elements in Earth's crust (% by weight)

Oxygen 49.13%, Silicon 26.0%· Aluminium 7.45%, Iron 4.2%,
Calcium 3.25%, Sodium 2.4%, Potassium 2.35%, Magnesium 2.35%,
Hydrogen 1%, All others 1.87%.

Principal Elements in the Hydrosphere (% by weight)

Oxygen 85.89%, Hydrogen 10.82%, Chlorine 1.90%, Sodium 1.06%, All others 0.33%c

Acceleration of Gravity (g)

At any latitude λ and height h (in meters) above sea level, $g=980.616-2.5928 \text{ Cos } 2\lambda + 0.0069 \text{ Cos}^2 2\lambda - 0.003\,h$

ATOMIC WEIGHTS

For the sake of completeness all known elements are included in the list. Several of those more recently discovered are represented only by the unstable isotopes. The value in parenthesis in the atomic weight column is, in each case, the mass number of the most stable isotope.

Name	Symbol.	At. No.	International atomic weight. 1961	1959	Valence
(1)	(2)	(3)	(4)	(5)	(6)
Actinium	Ac	89		(227)	
Aluminium	Al	13	26.9815	26.98	3
Americium	Am	95		(243)	3,4,5,6

Name	Sym-bol.	At. No.	International atomic weight.		Valence
(1)	(2)	(3)	1961 (4)	1959 (5)	(6)
Antimony, stibium	Sb	51	121.75	121.76	3,5
Argon	Ar	18	39.948	39.944	0
Arsenic	As	33	74.9216	74.92	3,5
Astatine	At	85		(210)	1,3,5,7
Barium	Ba	56	137.34	137.36	2
Berkelium	Bk	97		(249)	3,4
Beryllium	Be	4	9.0122	9.013	2
Bismuth	Bi	83	208.980	208.99	3,5
Boron	B	5	10.811	10.82	3
Bromine	Br	35	79.909	79.916	1,3,5,7
Cadium	Cd	48	112.40	112.41	2
Calcium	Ca	20	40.08	40.08	2
Californium	Cf	98		(251)	
Carbon	C	6	12.01115	12.011	2,4
Cerium	Ce	58	140.12	410.13	3,4
Cesium	Cs	55	132.905	132.91	1
Chlorine	Cl	17	35.453	35.457	1,3,5,7
Chromium	Cr	24	51.996	52.01	2,3,6
Cobalt	Co	27	58.9332	58.94	2,3
Columbium, see Niobium					
Copper	Cu	29	63.54	63.54	1,2
Curium	Cm	96		(247)	3
Dysprosium	Dy	66	162.50	162.51	3
Einsteinium	Es	99		(254)	
Erbium	Er	68	167.26	167.27	3
Europium	Eu	63	151.96	152.0	2,3
Fermium	Fm	100		(253)	
Fluorine	F	9	18.9984	19.00	1
Francium	Fr	87		(223)	1
Gadolinium	Gd	64	157 25	157.26	3
Gallium	Ga	31	69.72	69.72	2,3
Germanium	Ge	32	72.59	72.60	4
Gold, aurum	Au	79	196.967	197·0	1,3
Hafnium	Hf	72	178.49	178·50	4
Helium	He	2	4.0026	4.003	0
Holmium	Ho	67	164.930	164.94	3
Hydrogen	H	1	1.00797	1.0080	1
Indium	In	49	114.82	114·82	3
Iodine	I	53	126.9044	126.91	1,3,5,7
Iridium	Ir	77	192.2	192.2	3,4
Iron, ferrum	Fe	26	55.847	55.85	2,3

Name	Sym-bol.	At No.	International atomic weight 1961	1959	Valence
(1)	(2)	(3)	(4)	(5)	(6)
Krypton	Kr	36	83.80	83.80	0
Lanthanum	La	57	138.91	138.92	3
Lead, Plumbum	Pb	82	207.19	207.21	2,4
Lithium	Li	3	6.939	6.940	1
Lutetium	Lu	71	174.97	174.99	3
Magnesium	Mg	12	24.312	24.32	2
Manganese	Mn	25	54.9380	54.94	2,3,4,6,7
Mendelevium	Md	101		(256)	
Mercury, hydrargyrum	Hg	80	200.59	200.61	1,2
Molybdenum	Mo	42	95.94	95.95	3,4,6
Neodymium	Nd	60	144.24	144.27	3
Neon	Ne	10	20.183	20.183	0
Neptunium	Np	93		(237)	4,5,6
Nickel	Ni	28	58.71	58.71	2,3
Niobium (columbium)	Nb	41	92.906	92.91	3,5
Nitrogen	N	7	14.0057	14.008	3,5
Nobelium	No	102		(254)	
Osmium	Os	76	190.2	190.2	2,3,4,8
Osygen	O	8	15.9994	16.000	2
Palladium	Pd	46	106.4	106.4	2,4,6
Phosphrous	P	15	30.9738	30.975	3,5
Platinum	Pt	78	195.09	195.09	2,4
Plutonium	Pu	94		(242)	3,4,5,6
Polonium	Po	84		(210)	
Potassium, kalium	K	19	39.102	39.100	1
Praseodymium	Pr	59	140.907	140.92	3
Promethium	Pm	61		(147)	3
Protactinium	Pa	91		(231)	
Radium	Ra	88		(226)	2
Radon	Rn	86		(222)	0
Rhenium	Re	75	186.92	186.22	
Rhodium	Rh	45	102.05	102.91	3
Rubidium	Rb	37	85.47	85.48	1
Ruthenium	Ru	44	101.07	101.1	3,4,6,8
Samarium	Sm	62	150.35	150.35	2,3
Scandium	Sc	21	44.956	44.96	3
Selenium	Se	34	78.96	78.96	2,4,6
Silicon	Si	14	28.086	28.09	4
Silver, aregentum	Ag	47	107.870	107.873	1
Sodium natrium	Na	11	22.9898	22.991	1
Strontium	Sr	38	87.62	87.63	2

Name	Sym-bol.	At No.	International atomic weight. 1951	1959	Valence
(1)	(2)	(3)	(4)	(5)	(6)
Sulphur	S	16	32.064	32.066*	2,4,6
Tantalum	Ta	73	180.948	180.95	5
Technetium	Tc	43	....	(99)	6,7
Tellurium	Te	52	127.60	127.61	2,4,6
Terbium	Tb	65	158.924	158.93	3
Thallium	Tl	81	204.37	204.39	1,3
Thorium	Th	90	232.038	(232)	4
Thulium	Tm	69	168.934	168.94	3
Tin, stannum	Sn	50	118.69	118.70	2,4
Titanium	Ti	22	47.90	47.90	3,4
Tungsten (wolfram)	W	74	183.85	183.86	6
Uranium	U	92	238.03	238.07	4,6
Vanadium	V	23	50.942	50.95	3,5
Xenon	Se	54	131.30	131.30	0
Ytterbium	Yb	70	173.04	173.04	2,3
Yttrium	Y	39	88.905	88.91	3
Zinc	Zn	30	65.37	65.38	2
Zirconium	Zr	40	91.22	91.22	4

* Because of natural variations in the relative abundances of the isotopes of sulphur, the atomic weight of this element has a range of ± 0.003.

** The 1959 atomic weights are based on $O_2 = 16.000$ whereas those of 1961 are based on the isotope C^{12}.

REDUCTIONS OF WEIGHINGS IN AIR TO VACUO

When the weight *M* in grams of a body is determined in air, a correction is necessary for the buoyancy of the air. The following table is computed for an air density of 0.0012. The corrected weight $M + kM/1000$, values of k being found in the table.

Density of body weighed	Correction factor, *k*. Pt Ir weights	Brass weights	Quartz or aluminium weights
(1)	(2)	(3)	(4)
.5	+2.34	+2.26	+1.95
.6	+1.94	+1.86	+1.55

Density of body weighed	Correction factor, *k*.		
	Pt. Ir weights	Brass weights	Quartz or aluminium weights
(1)	(2)	(3)	(4)
.7	+1.66	+1.57	+1.26
.75	+1.55	+1.46	+1.15
.80	+1.44	+1.36	+1.05
.85	+1.36	+1.27	+0.96
.90	+1.28	+1.19	+ .88
.95	+1.21	+1.12	+ .81
1.00	+1.14	+1.06	+ .75
1.1	+1.04	+0.95	+ .64
1.2	+0.94	+0.86	+ .55
1.3	+ .87	+ .78	+ .47
1.4	+ .80	+ .71	+ .40
1.5	+ .75	+ .66	+ .35
1.6	+ .69	+ .61	+ .30
1.7	+ .65	+ .52	+ .21
1.8	+ .62	+ .52	+ .21
2.0	+ .54	+ .46	+ .15
2.5	+ .43	+ .34	+ .03
3.0	+ .34	+ .26	− .05
4.0	+ .24	+ .16	− .15
6.0	+ .24	+ .06	− .25
8.0	+ .09	+ .01	− .30
10.0	+ .06	− .02	− .33
15.0	+ .03	− .06	− .37
20.0	+ .004	− .08	− .39
22.0	− .001	− .09	− .40

DENSITY OF VARIOUS SOLIDS

The approximate density of various solids at ordinary atmospheric temperature. in the case of substances with voids such as paper or leather the bulk density is indicated rather than the density of the solid portion.

(Selected principally from the Smithsonian Tables)

Substance	Grams per cu.cm	Pounds per cu.ft.
(1)	(2)	(3)
Asbestos	2.0 – 2.8	125 – 175
Asphalt	1.1 – 1.5	69 – 94

Substance	Grams per cu. cm	Pounds per cu.ft.
(1)	(2)	(3)
Beeswax	0.96 - 0.97	60 - 61
Bone	1.7 - 2.0	106 - 125
Brick	1.4 - 2.2	87 - 137
Butter	0.86 - 0.87	53 - 54
Camphor	0.99	62
Caoutchoue	0.92 - 0.99	57 - 62
Cardboard	0.69	43
Celluloid	1.4	87
Cement, set	2.7 - 3.0	170 - 190
Chalk	1.9 - 2.8	118 - 175
Charcoal, oak	0.57	35
Clay	1.8 - 2.6	112 - 162
Coal, anthracite	1.4 - 1.8	87 - 112
Coal, bituminous	1.2 - 1.5	75 - 94
Coke	1.0 - 1.7	62 - 105
Copal	1.04 - 1.14	65 - 71
Cork	0.22 - 0.26	14 - 16
Flint	2.63	164
Glass, common	2.4 - 2.8	150 - 175
Granite	2.64 - 2.76	165 - 172
Graphite	2.30 - 2.72	144 - 170
Gum arabic	1.3 - 1.4	81 - 87
Gypsum	2.31 - 2.33	144 - 145
Ice	0.92	57.2
Ivory	1.83 - 1.92	114 - 120
Leather, dry	0.86	54
Lime, slaked	1.3 - 1.4	81 - 87
Limestone	2.68 - 2.76	167 - 171
Marble	2.6 - 2.84	160 - 177
Mica	2.6 - 3.2	165 - 200
Paper	0.7 - 1.15	44 - 72
Porcelain	2.3 - 2.5	143 - 156
Quartz	2.65	165
Resin	1.07	67
Rubber, hard	1.19	74
Rubber, soft	1.1	69
Sandstone	2.14 - 2.36	134 - 147
Silica, fused transparent	2.21	138
Slate	2.6 - 3.3	162 - 205
Starch	1.53	95
Sugar	1.59	99

Substance (1)	Grams per cu.cm (2)	Pounds per cu.ft. (3)
Talc	2.7 - 2.8	168 - 174
Tar	1.02	66
Wax; sealing	1.8	112
Balsa	0.11 - 0.14	7 - 9
Bamboo	0.31 - 0.40	19 - 25
Beech	0.70 - 0.90	43 - 56
Box	0.95 - 1.16	59 - 72
Cedar	0.49 - 0.57	30 - 35
Elm	0.54 - 0.60	34 - 37
Teak	0.66 - 0.88	41 - 55
Water gum	1.00	62
Willow	0.40 - 0.60	24 - 37

SURFACE TENSION

against air at 20°C

Acetone	23.7 dyne/cm	Glycerine	63.14 dyne/cm
Benzene	28.9	Mercury	487
Carbon tetrachloride	26.8	Methyl alcohol	22.6
Chloroform	27.1	Phenol	40.9
Ethyl alcohol	22.3	Toluene	28.4
Ethyl ether	17.0	Water	72.75

APPROXIMATE E.M.F.'s OF CELLS

Bichromate	2 volts		
Bunsen	1.9	Dry cell	1.5 volts
Daniell	1.08	Nickel-Cadmium	1.3
Grove	1.8	Nickel-Iron	1.4
Lechanche	1.46	Zinc-Siver oxide	1.8

Accumulator 2.0 volts (ranges 1.85–2 [illegible] volts)

PRESSURE OF SATURATED WATER VAPOUR IN MM OF MERCURY

Temp. °C (1)	Pressure mm (2)	Temp. °C (1)	Pressure mm (2)	Temp. °C (1)	Pressure mm (2)
−10°	2.16	11°	9.83	35°	42.14
− 9°	2.32	12°	10.50	40°	55.29
− 8°	2.51	13°	11.22	45°	71.84
− 7°	2.71	14°	11.97	50°	92.49
− 6°	2.93	15°	12.77	55°	118.0
− 5°	3.16	16°	13.62	60°	149.4
− 4°	3.41	17°	14.51	65°	187.6
− 3°	3.67	18°	15.46	70°	233.7
− 2°	3.96	19°	16.45	75°	289.1
− 1°	4.26	20°	17.51	80°	355.2
0°	4.58	21°	18.63	85°	433.6
1°	4.92	22°	19.81	90°	525.9
2°	5.29	23°	21.04	95°	634.6
3°	5.68	24°	22.35	99°	733.2
4°	6.09	25°	23.78	100°	760.0
5°	6.54	26°	25.18	101°	787.5
6°	7.01	27°	26.71	105°	906.1
7°	7.49	28°	28.38	110°	1974.6
8°	8.03	29°	30.08	150°	3570.1
9°	8.60	30°	31.79	200°	11664
10°	9.20				

N.B.—Near 100° C the boiling point of water rises by 37° C per rise of 10 mm atmospheric pressure.

RELATIVE HUMIDITIES FROM WET AND DRY BULB THERMOMETERS

(Exposed in Standard Screen)

The relative humidity is defined as the ratio, expressed as a percentage of the actual vapour pressure to the saturation vapour pressure at the temperature of the dry bulb. The dry bulb thermometer is an ordinary thermometer; the "wet bulb" thermometer is similar in design and has its bulb enclosed in a wick, the other end of which dips into water. By capillary action the thermometer bulb is wet and under the usually encountered conditions evaporation of the water lowers the temperature of the bulb. The difference in reading of the two thermometers is the "Depression of the wet bulb". The tables below give relative humidities for various values of the dry bulb temperature and the depression. Temperatures are in degrees Fahrenheit.

Depression of Wet Bulb	Dry Bulb Temperature (°F)														
	32°	34°	36°	38°	40°	42°	44°	46°	48°	50°	52°	54°	56°	58°	60°
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
1°F	89	90	90	91	91	91	92	92	92	93	93	93	94	94	94
2°F	79	79	80	81	82	83	84	84	85	86	86	87	87	88	88
3°F	—	70	70	72	73	74	75	77	77	79	79	80	81	82	82
4°F	—	—	60	63	65	66	68	69	70	72	73	74	75	76	77
5°F	—	—	—	54	56	58	60	62	63	65	66	68	69	70	71
6°F	—	—	—	44	47	50	52	56	59	59	60	61	63	64	65
7°F	—	—	—	—	39	42	45	47	49	52	54	55	57	59	60
8°F	—	—	—	—	30	34	37	40	42	45	47	49	51	53	55
9°F	—	—	—	—	—	26	29	33	36	38	41	43	46	48	50
10°F	—	—	—	—	—	18	22	26	29	32	35	38	40	42	44

Depression of Wet Bulb	Dry Bulb Temperature (°F)														
	62°	64°	66°	68°	70°	72°	74°	76°	78°	80°	82°	84°	86°	88°	90°
	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
1°F	94	94	95	95	95	95	95	95	95	96	96	96	96	96	96
2°F	88	89	89	90	90	90	90	91	91	91	91	92	92	92	92
3°F	83	83	84	84	85	85	86	86	86	87	87	87	88	88	88
4°F	87	78	79	79	80	80	81	82	82	83	83	83	84	84	84
5°F	72	73	74	75	75	76	77	78	78	79	79	79	80	80	81
6°F	67	68	69	70	71	71	72	73	74	74	75	76	76	77	77
7°F	61	63	64	65	66	67	68	69	70	70	71	72	72	73	74
8°F	56	58	59	60	62	63	64	65	66	66	67	68	69	69	70
9°F	51	53	54	56	57	58	60	61	62	63	64	64	65	66	67
10°F	46	48	50	51	53	54	56	57	58	59	60	61	62	63	63
12°F	37	39	41	43	44	46	48	49	50	52	53	54	55	56	57
14°F	27	30	32	34	36	38	40	42	43	45	46	47	49	50	51
16°F	18	21	23	26	28	31	33	34	36	38	40	41	42	44	45
18°F	10	13	16	18	21	23	26	28	30	31	33	35	36	38	39
50°F	—	5	8	11	14	16	19	21	23	25	27	29	31	32	34

THERMAL CONDUCTIVITY OF GASES (O°C)

Caloric/sec/cm^2/unit temperature gradient

Acetylene	.000045	Hydrogen	.0000327
Air	.0000568	Hydrogen sulphide	.0000287
Ammonia	.0000458	Methane (8°C)	.0000647
Argon	.0000389	Nitric oxide (8°C)	.0000460
Carbon dioxide	.0000307	Nitrous oxide	.0000350
Carbon monoxide	.0000499	Nitrogen	.0000581
Chlorine	.0000172	Oxygen	.0000563
Ethylene	.0000395	Sulphur dioxide	.0000184
Helium	.000339	Steam (100°C)	.0000519

ACID DILUTION BY VOLUME

The volume of pure acid (or water) which must be added to 50 cc of water (or acid) to give solutions of specific gravity shown. Temperature 20°C. Taken from curves prepared by W.W. Stiles, based on experimental determinations. The values are approximate only.

Nitric acid					
Sp. gr.	Acid cc added	Sp. gr.	Acid cc added	Sp. gr.	Water cc added
0.9982	0.0	1.14	18.5	1.27	43.2
1.00	0.2	1.15	20.3	1.28	39.3
1.01	1.1	1.16	22.3	1.29	35.5
1.02	1.9	1.17	24.4	1.20	31.7
1.03	3.0	1.18	26.7	1.31	28.2
1.04	4.1	1.19	29.3	1.32	24.9
1.05	5.2	1.20	32.1	1.33	21.8
1.06	6.4	1.21	35.1	1.34	18.8
1.07	7.7	1.22	38.3	1.35	15.9
1.08	9.1	1.23	41.8	1.36	12.9
1.09	10.6	1.24	45.6	1.37	9.9
1.10	12.0	1.25	49.4	1.38	7.1
1.11	13.5			1.39	4.5
1.12	15.1	Sp. gr.	Water cc added	1.40	2.1
1.13	16.8	1.26	46.9	1.408	0.0

Hydrochloric acid

Sp. gr.	Acid cc added	Sp. gr.	Acid cc added	Sp. gr.	Water cc added
0.9982	0.0	1.065	24.0	1.120	30.0
1.000	0 4	1.070	26. 0	1.125	26 4
1.005	1.4	1.075	30.0	1.130	2.32
1.010	2.7	1.080	33.7	1 135	20 0
1.015	4.1	1.085	37.9	1.140	17.2
1.020	5.6	1.090	42 2	1.145	14.8
1.025	7.1	1.095	47.0	1.150	12.4
1.030	8.6	1.100	47.8	1.155	10.0
1.035	10.2			1.160	8.0
1.040	11.8	**Sp. gr.**	**Water cc added**	1.165	5.9
1.045	13.8			1.170	3.9
1.050	15.9	1.105	42.2	1.175	2.1
1.055	18.4	1.110	37.6	1.180	0.6
1.060	21.1	1.115	33.7	1.185	0.0

Sulfuric acid

Sp. gr.	Acid cc added	Sp. gr.	Acid cc added	Sp. gr.	Acid cc added
0.9982	0.0	1.24	14.5	1.48	44.5
1.01	0.2	1.25	15.3	1.49	46.6
1.02	0.5	1.26	16.1	1.50	48.7
1.03	0.9	1.27	16.9		
1.04	1.3	1.28	17.8	**Sp. gr.**	**Water cc added**
1.05	1.7	1.29	18.7		
1.06	2.2	1.30	19.6	1.51	49.3
1.07	2.7	1.31	20.6	1 52	47.2
1.08	3.2	1.32	21.6	1.53	45.2
1.09	3.7	1.33	22.7	1.54	43.3
1.10	4.3	1.34	23.8	1.55	41.4
1.11	4.9	1.35	25.0	1.56	39.5
1.12	5.5	1.36	26.2	1.57	37.7
1.13	6.2	1.37	27.4	1.58	36.0
1.14	6.9	1.38	28.6	1.59	34.3
1.15	7.6	1.39	29.8	1.60	32.8
1.16	8.3	1.40	31.1	1.61	31.4
1.17	9.0	1.41	32.5	1.62	30.0
1.18	9.7	1.42	33.9	1.63	28.6
1.19	10.5	1.43	35.4	1.64	27.2
1.20	11.3	1.44	36.8	1.65	25.9
1.21	12.1	1.45	38.4	1.66	24.6
1.22	12.9	1.46	40.2	1.67	23.3
1.23	13.7	1.47	42.3	1.68	22.0

Sulfuric Acid					
Sp. gr.	**Water cc added**	**Sp. gr.**	**Water cc added**	**Sp. gr.**	**Water cc added**
1.69	20.7	1.74	14.3	1.79	7.6
1.70	19.4	1.75	13.0	1.80	6.0
1.71	18.1	1.76	11.7	1.81	4.4
1.72	16.9	1 77	10.4	1.82	2.8
1.73	15.6	1.78	9.1	1.83	0.5

GENERAL RULES REGARDING BEHAVIOUR OF METALS AND CERTAIN COMPOUNDS

Action of Metals on Salts: Any metal will replace any other metal below it in the series thus:

$$\begin{gathered} Mg + FeSO_4 \rightarrow MgSO_4 + Fe \\ Zn + CuSO_4 \rightarrow ZnSO_4 + Cu \\ Sn + 2AgNO_2 \rightarrow Sn(NO_3)_2 + 2Ag \\ Cu + Hg(NO_3)_2 \rightarrow Cu(NO_3)_2 + Ag \end{gathered}$$

This is the fundamental principle of the Daniell Cell. The voltage of such a cell depends upon the difference between the electrode potentials of the metals employed. Thus the Zn–Cu couple gives a greater E.M.F. than the Zn–Pb couple or the Fe–Cu couple. Refer to the "oxidation potentials of elements."

Action of Metals on Salts: Metals above H_2 react with HCl and dilute H_2SO_4 replacing the H_2.

$$\begin{gathered} Zn + \text{dil. } H_2SO_4 \rightarrow ZnSO_4 + H_2 \\ Sn + 2HCl \rightarrow SnCl_2 + H_2 \\ Cu + \text{dil. } H_2SO_4 \rightarrow \text{no reaction} \end{gathered}$$

Metals above Pt react with HNO_3 and not concentrated H_2SO_4

$$\begin{gathered} 2Ag + 2\text{ conc. } H_2SO_4 \rightarrow Ag_2SO_4 + SO_2 + 2H_2O \\ 3Zn + 8\text{ conc } HNO_3 \rightarrow 3Zn(NO_3)_2 + 2NO + 4H_2O \\ 3Cu + 8\text{ dil. } HNO_3 \rightarrow 3Cu(NO_3)_2 + 2NO + 4H^2O \end{gathered}$$

The acid first oxidizes the metal and the reaction may be explained as follows:

Some of the acid takes on water and ionizes thus:

$$2HNO_3 + 4H_2O \longleftrightarrow 10\,OH^- + 2N^{+++}_{++}$$

Nitrogen gains three electrons and copper loses two electrons :

$$2(N^{+++}_{++} + 3e) + 3(Cu - 2e) \rightarrow 3Cu^{++} + 2N^{++}$$

Some of the acid ionizes as follows :

$$6HNO_3 \longleftrightarrow 6H^+ + 6NO_3$$

$$3Cu^{++} + 6NO_3^- \rightarrow 3Cu\,(NO_3)_2$$

$$10\,OH^- + 6H^+\ 2N^{++} \rightarrow 2NO + 8H_2O$$

$$3Cu + 8HNO_3 \rightarrow 3Cu\,(NO_3)_2 + 2NO + 4H_2O$$

In regard to ease of reduction of oxides : The metallic oxides down to and including Mn cannot be completely reduced to the metal state, even in a current of hydrogen. The oxides of Cd and succeeding metals are easily reduced, and far down the list. the oxides of silver, platinum, mercury, and gold are reduced (decomposed into metal and oxygen) even by heat alone.

In regard to ease of rusting (oxidation in tne air) : The alkali and alklaine earth metals rust very rapidly and with considerable evolution of heat. All the metals down to copper rust with comparative ease. The metals below copper do not rust. Assuming the electrolytic theory of the process of rusting to be true, these facts are just about what might have been predicted.

In regard to the occurence of the metals in the free state in nature: Natural waters are frequently dilute solutions of carbonic, nitric, humic, etc. acids. As such they contain displaceable hydrogen. Metals above hydrogen in the E.M.F. series scarcely, if ever, occur in the free state in nature, but are practically without exception found in the combined state, as sulfides, carbonates etc. Metals below hydrogen are frequently found in the free state in nature. Thus gold is found in the form of nuggets of metallic gold. However metals below hydrogen are also found in the combined state, as cinnabar HgS etc.

In regard to action of the metal on water : The alkali and alkaline earth metals displace hydrogen from water even in the cold, and with evolution of much heat. Mg and succeeding metals will displace hydrogen from steam.

In regard to the solubility and stability of hydroxides : The alkali metal oxides have great avidity for water, forming hydroxides. The alkaline-earth metal oxides react with less readiness, forming hydroxides. MgO reacts slowly and pletely with water, forming the hyroxide. All the other metallic oxides and hydroxides are insoluble in water and have no perceptible reaction there with. When a solution of NaOH acts on solutions of salts of the metals, the alkali metal salts are not precipiated. The alkaline earth metal salts are not precipitated unless in very concetnrated solution. All the other metal solutions are acted upon, with precipitation of hydroxides, except in the case of copper which first gives copper hydroxides (blue) and which, on warming, changes to copper oxide (black). Also in the case of arsenic, no precipitate falls, sodium arsenite being formed In the case of the last metals in the series, the oxide is precipitated, instead of the hydroxide, thus NaOH acting on salts of Sb, Hg, Ag, Pd, Pt and Au, causes a precipitation of the oxides of these metals. Bismuth as an exception, gives a normal hydroxide.

In regard to carbonates: The alkali metals form normal stable, soluble carbonates, not easily decomposed on heating. The alkaline-earth metals form normal carbonates, which are insoluble in water and which decompose upon heating,leaving the oxide,carbon dioxide being evolved. When sodium carbonate solution acts on solutions of all the other metals, as rule, a basic carbonate is precitipated being insoluble in water, and decomposed by heat into oxide and carbon dioxide. If the solution is cold, Ag, Hg, Cd, Fe and Mn give normal carbonates. If the solution is warm St, Hg, Ag, Pd, Pt and Au give a precipitate of the oxide, instead of the carbonate, thus showing the instability of the carbonates of the lowest metals in the series.

In regard to nitrates: The nitrates of the alkali metals decompose when strongly heated forming the nitrite and oxygen. The nitrates of the heavy metals, down to and including copper, decompose when heated forming the oxide of the metal, oxygen and nitrogen dioxide. Mercury nitrate when heated yields mercury, oxygen and nitrogen dioxide.

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GREEK ALPHABET

Greek letter	Greek name	English equivalent	Greek letter	Greek name	English equivalent
Α α α	Alpha	a	Ν ν	Nu	n
Β β	Beta	b	Ξ ξ	Xi	x
Γ γ	Gamma	g	Ο ο	Omicron	o
Δ δ	Delta	d	Π π	Pi	p
Ε ε	Epsilon	e	Ρ ρ	Rho	r
Ζ ζ	Zeta	z	Σ σ ς	Sigma	s
Η η	Eta	e	Τ τ	Tau	t
θ θ ϑ	Theta	th	Υ υ	Upsilon	u
Ι ι	Iota	i	Φ φ ϕ	Phi	ph
Κ κ	Kappa	k	Χ χ	Chi	ch
Λ λ	Lambda	l	Ψ ψ	Psi	ps
Μ μ	Mu	m	Ω ω	Omega	o

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